Proposal for a Spread Spectrum Transponder Payload On the International Space Station

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Abstract

A satellite payload for the International Space Station is proposed, which would provide high-bandwidth, wide-area data communications capabilites for radio amateurs. Key features of the system are a simple space segment and low cost ground stations. Varying tiers of service can be provided depending on end-user equipment investment , from low-cost paging, through digital voice, video, and high-speed data communications.

1 Introduction

1.1 Vision and Goals

The design, construction, and deployment of an experimental payload for the EXPRESS Pallet on the International Space Station (ISS) is proposed. The payload, to be known as the Spread Spectrum Wideband Transponder (SSWBT), is designed with the following goals in mind:

- Low cost digital voice communications
- Digital Videoconferencing "for the masses”
- High bitrate, low-latency data, transfer
- Development of Spread Spectrum technology in the amateur community
- Open space communications to the average amateur
- Room for future growth and expansion

We envision four general tiers of use for the SSWBT:

Ultra-low bitrate (< 1 kilobits/second) These would be handheld size stations, with simple patch antennas. These would be useful for paging, position reporting/homing (APRS), emergency distress beacons, and vehicle and property location systems. These systems could be made without receiving equipment if that functionality was not needed.

Low bitrate (~10 kb/s) Full duplex digital voice and data communications. With modern vocoders, 10 kb/s can provide quality better than that typical of FM repeaters. The system will be capable of both user-to-user (QSO style) full duplex, **as** well as roundtable (repeater or **traffic** net-style) communications. These stations could be mobile-mounted, portable, or simple home stations. Small patch antennas would be used, thus avoiding the need for aiming or moving the antennas.

Medium bitrate (~150 kb/s) Digital **Videocon**ferencing, web serving, and other modern internet-style applications. These will be stations which are more well equipped, and most likely, not mobile. These will require moderately sized (**~1** foot) dish antennas and some mechanism for aiming them.

High bitrate (1 - 1.5 Mb/s) There will not be many of these stations, perhaps **6-10** per continent, placed at strategic locations so at least one is visible during any part of a satellite pass. These stations can transmit large quantities of data, typically requested by the lower bandwidth user stations. These could be **internet** access points, and could also broadcast (or **multi**cast) high quality video feeds. This would be ideal for applications such as broadcasting meetings or other important amateur events. These stations may require large dishes with accurate pointing systems, and higher power amplifiers

One of the greatest features of the SSWBT concept is that while more complex and expensive systems with high power and gain will be necessary to transmit at the higher bitrates, nothing extra will be necessary to receive these transmissions. Thus, the low bandwidth systems, besides being useful for voice communications between comparable users, can be effectively used for such applications as web browsing, and file retrieval (ftp). Ten **kilobits** per second is plenty of bandwidth for requesting web pages, which would be served by the medium or high bandwidth systems. Highly asymmetric links are very useful for these applications.

1.2 Why ISS and EXPRESS Pallet

What has often held back amateurs from deploying more advanced digital communications systems has been the problem of critical density. High bandwidth often requires microwave frequencies and line of sight propagation. These are difficult to achieve in terrestrial systems unless there are enough users in a particular area. By using a satellite, these good paths can be guaranteed, while at the same time providing tremendous coverage area which would be impossible otherwise. The need to reach critical densities for deployment is avoided.

The International Space Station represents the ideal satellite carrier for the SSWBT. Because it will be placed on the ISS, the SSWBT can be quickly and inexpensively deployed, without the development of its own launch vehicle. It will serve as an ideal **testbed** for **a** possible future network of **microsatellites**, and local terrestrial transponders to provide complete earth coverage. Since the satellite will be accessible worldwide, technology and development can be shared, improving the economies of scale, and making it more likely that the system will catch on in significant numbers.

The EXPRESS Pallet is ideal for this type of experimental payload. The SSWBT will be small and light, due to its tiny patch antennas and very simple electronics. It will consume little power, probably less than **100W**, due to the relatively low and nearly circular orbit of the ISS. It will require no interaction with other systems on the ISS, and its only controls will likely be to enable or disable it. The SS transmissions of the SSWBT will not interfere with the other experiments on the Pallet or the rest of the ISS. The nadir-pointing attribute of the Pallet makes line of sight contact possible.

2 Technical

2.1 Features

- Direct Sequence Spread Spectrum (DSSS) Modulation
- 5.7 GHz Band Uplink
- 3.3 GHz Band Downlink
- 50 MHz wide signal bandwidth
- Automatic Power Control
- Scalable bitrate

2.2 Capabilities

This system will be able to accommodate over 500 digital voice conversations, dozens of high bitrate video conferencing sessions, and a Tl-class data link, all at once. Stations within 400 miles of the point directly below the ISS will be able to access these facilities, providing a coverage area of about half a million square miles. It can provide high data rate, asymmetric data links to small mobile users, with tiny patch antennas. User systems will have low power consumption.

2.3 General Architecture

In order to receive and demodulate SS signals from hundreds of users at one time, hundreds of demodulators would be necessary on the ISS. Instead, the SSWBT simply amplifies and retransmits the signals which it receives. This allows the ground stations to each pick out and demodulate their own signals.

A key advantage of the SSWBT is its very simple space segment. The payload will consist of a linear transponder, and a simple "carrier" signal generator,. All of the complexity will be in the ground stations. This allows for easy Changes to the modulation for-- mat, and avoids the need for complex and expensive radiation-hardened DSP components.

2.3.1 Modulation and Coding

DSSS Modulation will be used, with binary phase-. shift keying (BPSK). The manner in which spreading codes are assigned will be discussed below. Whatever the bit rate which a station is transmitting at, it will always use the same chipping rate, 25 MHz. Thus, all signals will have the same occupied bandwidth of 50 MHz, and processing gain will be inversely proportional to bit rate. Nyquist filtering will be used to keep the occupied bandwidth to less than 50 MHz. Effective radiated power will be in direct proportion to bit rate, so that energy per bit is constant for all stations.

In order to provide more reliable communications,, with lower power, and higher user capacity, forward error correction (FEC) will be used extensively. The most likely candidate is Convolutional coding and Viterbi decoding. ASICs are commonly available now which are capable of high data rates with rate 1/2, and 1/3 codes and constraint lengths of 7 or 9. Other options might include combining convolutional codes with Reed-Solomon codes, or even using turbo codes. Again, these are all issues for the ground stations, and so could be changed without touching the transponder. Different FEC systems could even be used for each of the different data rates, although that would probably not effectively reuse components. Multiple schemes could be used concurrently, allowing experimentation to coexist with normal use.

Different spreading codes correspond different "channels" of communications. Each station will have an assigned "hailing code," to which it will always be listening. When station A wishes to transmit to station B, station A will transmit using B's hailing code. In this first packet, A will send a code pair, one for a to use when talking to B, one for the reverse link. They will then use these codes for the duration of their communication. As long as the set of all codes is sufficiently large, collisions (different transmitters using the same codes at the same time) can be avoided.[1]

2.3.2 Automatic Power Control

Automatic power control (APC) is necessary to make this system work. Without it, stations closer to the satellite would swamp out the ones further away. APC guarantees that all signals will be received at the same strength, maximizing the number of them that can be decoded successfully.

The pilot signal will be used as the reference power level. When a station is transmitting, it must simultaneously receive and decode its own signal, as well as the pilot signal. The transmitting station must constantly adjust its power up or down to make its downlink signal equal in power[2] to the pilot signal. The actual downlink power received will vary, but the relative levels of the many signals and the pilot signal will remain the same.

2.3.3 Space Segment

The space module, the SSWBT itself, is a simple linear transponder, with only one addition. A simple (and small) 10 dBi, circularly polarized patch antenna receives the many uplink signals at 5.7 GHz. After being amplified and filtered, they are downconverted to IF. At IF, the signal passes through a 50 MHz wide channel filter, and an AGC amplifier. Then a pilot signal is injected, and the combined signal is then upconverted to 3.3 GHz. After it is amplified (about 25W output), it is retransmitted back to earth via another 10 dBi circularly polarized patch antenna.

The pilot signal is very crucial to the operation of the system as a whole. It allows the ground stations to have a reference power so that they are able to provide near perfect power control. It also provides a signal timing and doppler reference which the ground stations can also use to ease the problem of getting code and data synchronization.

2.3.4 Ground Segment

A minimal ground station, capable of transmitting digital voice, will be the typical end-user system. Such a station will use circularly polarized patch antennas, just like the satellite. It must have at least three despreading channels. One to monitor the pilot signal, one to monitor the station's own transmitted

[1] In the case of two stations transmitting on a third's hailing channel at the same time (a collision), both should detect it. Normal random backoff procedures would be used. High bandwidth, high utilization base stations should have multiple hailing channels to avoid this.

[2] Actually, energy per bit will be controlled. This will allow signals with varying bit rates on the same channel.

power and timing, and one for useful reception of signals from other stations. Since all of the signal processing associated with despreading channels will be done in digital logic in FPGAs or ASICs, adding more will not be difficult. Additional channels will be useful for receiving many datastreams at once.

For transmitting, a power output of 1 Watt (and the capability to reduce that output power) is all that is necessary for communication. Stations of this class should cost well under $1000, and could easily be made mobile. Again, while these stations will only be able to transmit at low bitrates, they can receive at the highest rates.

A high end home station, if it is to transmit at 150 kbit/s, would need to produce 15 times the effective power output. Most of this gain would to be provided by the antenna, so that commonly available integrated power amplifiers in the 3-5 W range could be used. This implies the need to point the antenna, however, and that may add to the cost of some installations. Otherwise, all hardware would be the same as the standard end user system. The receive antenna could still be the same patch as used by low end stations.

High bandwidth, regional base stations, which need to transmit in the 1 Mbps range, would have to have moderate sized dishes, and power outputs in the 10-25W range (this can be traded off against antenna gain). The receive antenna could again be the same small patch, but better results on distant passes, near the horizon, could be had with small, aimable dishes. This would give a regional base station more coverage, increasing the probability that one is always in view of the satellite.

Receive equipment on the regional base stations would be similar to the user stations, with the addition of many more despreading channels in the hardware. This would allow many more simultaneous connections and requests, allowing the station to keep its transmitter busy supplying data.

3 Conclusions

The SSWBT will open up a whole new world of digital communications to the amateur radio community. By taking advantage of underutilized spectrum, and advanced communications techinques, we will finally be able to interconnect the ham world with a high bitrate, integrated network. This will open up the possibility of digital videoconferencing, digital voice communications, and high speed data transfer. The ISS and the EXPRESS Pallet will make this all possible by solving the problems of line-of-sight propagation and geographic coverage.