An Enhanced Digital ARISS for ISS

Jan A. King, W3GEY

Introduction:

Amateur Radio should be proud of the tremendous progress that has been made in qualifying and operationally using the ARISS station on ISS. The success of the ARISS program helps to assure a long-term relationship between NASA, ARRL, AMSAT-NA, and ARISS International Partners. While returning from the AMSAT-NA 2002 Annual Meeting I read several papers given to me by Frank Bauer, KA3HDO. As I have had little connection with the ISS activities I had not been paying attention to many of the operational aspects of the program. What I learned is that we now know clearly how to obtain optimum results from the equipment that exists on both ends of the link and how to bring a sense of standardization to the process, which allows school kids to talk to and learn from the astronauts. In addition, maximum political and social benefit is now being achieved as well.
The only thing that struck me as a shortcoming in the entire operation was that schools were limited to a rigid contact time of 10 minutes. I realized, upon reflection that this may be intentional as it limits the amount of time the astronaut must spend on this activity to a level that could be considered as "overhead" by ISS program officials and managers. I believe, however, it would be useful to expand both the quality and capacity of the system so that, should additional time become available to the astronauts for direct student training, an advanced system supporting longer contact time per orbit and providing enhanced voice data and video capabilities will be in place .

One key to the expanded use of the station is the existence of the four antennas (WA-1 thru WA-4) that are now mounted on the exterior of the vehicle. [Way to go ARISS team!] Among the options are earth-viewing and space-viewing antennas that cover the L-Band and S-Band frequencies available to the Amateur Satellite Service.

The second key to success of an expanded capability is the desire on AMSAT-NAs part to explore digital voice and data capabilities on our future satellites. KA9Q, in particular, has proposed that a new digital TDMA or CDMA standard be developed that would exploit not only new spacecraft technology but, new user ground station technology which would be co-developed with the spacecraft hardware and software. This development approach would be "new ground" for AMSAT.

A digital approach to the entire radio system could make use of current multiplexing and forward error correction techniques and would make possible the transparent sharing of voice, data and video modes of operation. Certainly, the ability to port the two-way ISS data stream to/from the Internet would greatly enhance the interactive possibilities between ISS and the public.

Conceptual Summary:

It is not my purpose here to design this future system but rather, to summarize what could be achieved with a straight-forward development effort on AMSAT-NA's part.

ISS Hardware/Software:

The ISS hardware would make use of the L/S band spiral antennas associated with the WA-2 and WA-3 locations. The 2 meter/70 cm FM radio currently used would be swapped for a regenerative (demod/remod) 23cm/13cm transceiver/transponder. As an astronaut must be able to use the system directly as a communications terminal, the transponder link must be able to be broken so that the unit serves as a transceiver as well. A key design requirement for the ISS radio system would be the integration of voice, data and (slow-scan or medium scan) video services, possibly simultaneously, onto the RF data link. The on-board hardware that interfaces to the station could take the form of a local TCP-IP router (or equivalent) and would receive and send higher speed packet data from/to participating ground stations. At ISS, a group of devices operated by the ham astronaut could be merged at the router, which would then drive the two-way radio link. The uplink frequency band would be the 1260-1270 MHz band and the downlink would be in the 2400-2417 MHz band. The downlink choice here may need to be re-evaluated considering the interference threat currently being imposed upon the Amateur Service by Part 15 devices (the growth of 802-11b being one of the largest issues). RF emissions, of course, must be compliant with ISS and STS EMI/EMC requirements.

The transponder/router would have to utilize link protocol choices that would allow the merger of simultaneous data sources, assure sufficient link security (in some desired cases) and provide forward error correction coding (which will greatly enhance the link performance and reduce the effects of short duration link fading). ISS is in a low orbit and the frequencies proposed are in the low microwave region. There will be a lot of Doppler shift (in excess of 100 kHz per overhead pass at S-Band). The hardware and software at both ends of the link must properly deal with this.

User Ground Station Hardware/Software:

The current hardware "specified" for school contacts includes a directive antenna (yagi system) that is pointed using an open loop, program track method (just like all OSCAR satellites are tracked). While this approach is a useful demonstration of the skills more generally required for satellite tracking, using digital communications methods would allow excellent communications link performance without using a tracking antenna at the earth station. At the frequencies proposed, it would be possible to use very small range compensating antennas (also known as iso-flux antennas) that provide higher gain on the horizon and lower gain at high elevation angles where the satellite is closer to the observing ground station (a multi-turn quadrifilar helix is one example of such an antenna). Such antennas would be very small and are even circularly polarized which will reduce signal fading. The transceiver units to be used are a main topic of discussion since they would be designed from scratch as proposed by KA9Q. This is important because the transceivers are proposed as an entirely new mode of communications for amateur radio into the future. These transceivers would be designed and developed by a team of AMSAT (and other) radio amateurs in a mode much like our satellites. There is a need then, to reproduce them, first in small quantities and then in much larger quantities. The TAPR TNC model comes to mind. What is really new in this case, is the concept of using them first with ISS and then propagating their use into the more general amateur population, rather than turning things around. And the reason for doing this is because I assume we will be able to have NASA assist us in making this happen.

Just like the ISS hardware, these transceiver terminals will provide multi-mode capability. Voice, data and video are a must (probably simultaneously). The transceiver would thus have an interface to a computer, a microphone jack and an interface to a video system, although, from a practical standpoint the microphone and video interfaces would be via a sound card and video card within the computer. Most importantly, the transceiver would be capable of being interfaced directly to the Internet, although, from a practical standpoint that may take place by having a small computer to serve as a router between the transceiver and the Internet modem. This then brings up another key feature that supports the current ISS school program. Some schools participate by connecting to telephone conference bridge. They do not have a ground station at their school. Remote stations receiving the ISS are patched into the bridge and audio is provided during an ISS over-flight of each participating ground station. With a new digital transmitter/receiver design it would be possible to locate unattended ground stations anywhere they are needed around the world. They can be tied together via the Internet. This, very simply, replaces the telephone bridge with the Internet. It makes the lowest common denominator to adding a station to the new ISS/ARISS network become…the availability of an Internet connection. That means a significant practical increase in coverage for the new “network” compared to current circumstances. Unattended stations could be added even in places such as islands in the Pacific where currently the ARISS coverage is not practical. Such a scheme preserves the options which the schools presently have. They may still set up their own station and communicate directly with ISS, which for some groups will always have great appeal. Or, they can participate by using the ARISS network, which can now be extensively expanded. In fact, an option exists for a school to use BOTH modes of interaction. Schools could team together to expand objectives. I’m certain the limitation will quickly become astronaut time limitations. Of course, with something as important as this, maybe ARISS could attract more schedule "attention." (Wet dream here).

An important advantage of an all-digital mode is the ability to significantly improve link performance by using forward error correction coding. KA9Q has been reviewing a variety of coding options but, certainly using both convolutional and block codes provides the most significant advantage. Depending on whether coherent versus non-coherent demodulation standards are ultimately employed, the advantage is link performance is between 6 dB and 10 dB (a factor of 4 to 10). It is important for amateur radio to advance in this area of radio frequency technology as we are very significantly behind industry in our utilization of this critical set of technologies. This weakens the entire ability of amateur radio to justify its use of the radio spectrum. WE MUST SHOW RESOLVE TO MOVE FORWARD IN THIS AREA!

A final benefit of this approach is that the ISS can simply act as an active digital transponder when the astronauts are not available by simply using the ISS equipment in the demod/remod transponder mode.

What Would Be the Next Step?

I'll eventually attach a summary of some requirements for the elements of the system as I envision it. Call it a straw man system concept. It doesn't have to stand. I would think the first step would be to get reactions from within the organization and, of course, first from Frank Bauer. There may well be stumbling blocks to the idea of which I have no knowledge. I'm sure similar ideas have already been discussed to some extent. I think the idea of moving forward with Phil Karn's ideas on ISS and then using ARISS as a platform for leveraging the terminal development so that we can afford to get the terminals into mass production for all of us IS a new thought. So I think the next steps, in order, are:

1) Get buy-in from the AMSAT-NA BOD and advisor group.

2) See if the ARISS team would support this concept as the next generation of ARISS system (it would be about 3rd generation if I understand things correctly).

3) Propose a detailed concept and develop cost estimates.

4) Propose the system to NASA and request funding for the program. It would certainly be fair to propose some cost sharing, although much of our manpower would be free already.

5) Develop a real schedule, plan, and management team (probably including but not limited to the current ARISS team).

6) Execute the program, if funded by NASA. Do it anyway if they don't.