

QRP to the ISS

Contacting the International Space Station with a few watts and a shoestring budget antenna.

Doug Cook, KD5PDN

From work-sat.com - reprinted with permission of the ARRL.

There's a Kenwood TM-D700A transceiver traveling 4.3 miles every second as it dashes across the sky 240 miles above our antennas. This D700A is the Amateur Radio station aboard the International Space Station (ISS), which zips around the Earth every 90 minutes.

This radio serves several roles. It can be used to contact schoolchildren during flyovers. Astronauts can talk with students using Amateur Radio equipment set up in the classroom by a local volunteer. Astronauts can also call down and talk to operators in their spare time — many have ham licenses themselves. Finally, it could serve as a backup communications method should the multimillion-dollar space communications system falter.

It's usually operating 24/7. This radio has a function known as a digipeater. Amateur Radio operators can send packets of data to it and the ISS will retransmit it back to Earth. It's like text messaging or SMS — information is being exchanged. We call it APRS (Automatic Packet Reporting System) and it's useful for distributing real-time reports of information.

An FM transmitter with packet capabilities, a terminal node controller (TNC), 50 W of power and an omnidirectional whip antenna should allow ISS contacts. I discovered how to use my Kenwood TM-D710A transceiver to make contacts in this manner. A search on the Internet will locate websites and several YouTube videos that show how to set up this radio.

My Yaesu VX-8R had APRS capabilities thanks to its built in packet modem. These radios are handy on the ground for communications, but 5 W to the omnidirectional flexible antenna probably would not reach the ISS in most attempts even under ideal conditions. We need to get 5 W of power to an orbiting station traveling at 17,000 MPH. A beam antenna can best fill this role.

A beam antenna can take most of the radio's output energy and focus it in one direction. I decided to build a tape measure antenna since its cost is minimal and it requires only basic crafting skills. The tape measure antenna is a modified Yagi design with elements made of the metal blade from a tape measure, cut to a specific frequency and positioned to create a focused radiation pattern.



Figure 1 — The director elements can be moved closer in or out to optimize the SWR a little. Don't let them touch.



Figure 2 — This is a close-up view of the Yaesu VX-8R and camcorder assembly.

Tape Measure Antenna

I began my antenna using the design on Joe Leggio's, WB2HOL, website (theleggios.net). I also consulted a Yagi antenna calculator on James Stewart's, N3DNO, website (bfn.org/~bn589/antenna.html). I wanted my antenna optimized for 145.825 MHz — the

frequency of the ISS digipeater. The lengths of the elements from the calculator came out a bit longer than the design published by WB2HOL. I decided to cut mine to this length knowing that I could trim them down if needed. After assembly I used an MFJ-259B antenna analyzer to tune it to an optimum SWR.

My original length of the director element was set at the original spec of 12.5 inches. My SWR measured 6.8 as constructed. I maneuvered the driven elements closer and the SWR lowered just a little (see Figure 1). I next varied the forward director element until it reached the best SWR reading at 1.0. This ended up about 4.5 inches from the driven element — a lot shorter than the original plan's specified 12.5 inches or even the Yagi calculator result. The distance from the driven element to the reflector remained unchanged at 8 inches as the design specified. I didn't seem to get much change in varying this distance. I trusted the readings from the analyzer so I finished the assembly. The nice thing about PVC pipe is that you can easily adjust and cut a new piece if you have to change it later.

My total cost was about \$15 including hardware. I used a spare length of RG-174A cabling with an SMA male connector so it would hook up to my VX-8.

Enhancements for Ease of Use

The tape measure antenna is designed for handheld use. However, I wanted to record the audio and video of the encounter and desired an assembly that could mount to a common camera tripod so my hands would be free. I fabricated a steel slotted bracket bought at a hardware store to attach the antenna assembly to my radio (see Figure 2). I bent the steel bracket into an L-shape. At the far end of the L I attached a camcorder so it could record the audio output and video the radio display as well as act as a counterweight for the antenna assembly. The camcorder was attached with a standard ¼ inch bolt trimmed to securely mate the bracket to the existing camera's tripod mount.

A second smaller L bracket was made and attached to the larger L bracket by wing nuts and bolts. This bracket holds the VX-8, which itself attaches by its belt clip. The whole assembly attaches to a traditional camera tripod secured by a ¼ inch wing nut. This attachment point is its balance point and the antenna can be aimed with one hand after adjusting your tripod's positioning levers to offer just enough resistance to keep the antenna aimed without drifting (see Figure 3).

Planning for Flyovers

Amsat.org offers prediction services but I chose to use heavens-above.com to discover upcoming ISS flyover opportunities. This online utility can project both visible passes and all passes. I chose "all passes" to increase the number of opportu-

nities. If you find a “visible pass” it will be easy to keep your antenna pointed accurately, but passes will be less frequent (see Figure 4). The predictions plot the opening time of the expected flyover window, the minimum angle compass bearing from your position at the beginning, the maximum elevation and the bearing at the end of the flyover. A hardcopy and a synchronized watch are the only tools you’ll need to help aim the antenna in the proper position at the correct time. Once you start hearing the ISS signal, your transceiver’s S meter and audio output will offer cues toward aiming.

You can also use NASA’s online app (spaceflight1.nasa.gov/realdatasightings) to predict overflights. The NASA predictor may be more up to date if maneuvers are underway before the satellite elements data gets updated on other online resources.

Satscape (free) is a very good *Java* application that can be used with *Windows*, *Mac* and *Linux*. *Windows* software includes *NOVA* for *Windows* (\$59.95). Mac users can consider *MacDoppler* (\$98). In addition to prediction, *NOVA* and *MacDoppler* can control automated systems for antenna rotators.

For smartphone and tablet users other programs I find useful are *ProSatHD* (\$9.99 for iOS) and *PocketSat3* (\$24.99 for iOS or Android). I use *ProSatHD* more often. It offers an updated display of the satellite in its current position. This software provides a real-time position of your target along with a circle of its horizon to let you know when the satellite is nearly in position to make contact. It offers an overflight plot that can assist in planning your antenna trajectory for your hand tracking and offers real-time elevation data to determine the antenna’s angle of elevation for best reception. You will want to update the database before leaving for a remote location so you have the most recent and accurate satellite position data elements.

The program also offers calculations to estimate the effects of the Doppler shift of the frequency as it approaches and recedes. I found that adjusting my frequency was not necessary in any of my attempts in the 2 meter band but 70 cm band operations often do require adjusting for the effect since Doppler shifting is more pronounced there.

Finally, it pays to see if the digipeater is turned on. Websites such as the ISS Fan Club at www.issfanclub.com will have reports on the status of the ISS’s Amateur Radio station. The website ariss.net displays the latest APRS beacon information, or you can look at the Twitter feed twitter.com/RS0ISS to get the latest update. This can avoid the disappointment of waking up in the middle of the night only to find the station’s radio is off.

Beaconing or Messaging

The APRS functions of the built-in modem and TNC include transmitting and



Figure 3 — This is how the setup looks ready for action. A protractor is mounted below the antenna with a washer on a string to “display” the elevation angle. On the left are the handheld transceiver and the camcorder attached to a homebrew mounting bracket. The whole assembly is being held on a standard photo tripod.

receiving both beacons and messages. For your first ISS flyover, I recommend using the beacon function. Radios with APRS beacon functions let you set up a message to be included with your beacon. For the VX-8 this setting is labeled BEACON STATS TXT. Once you are more familiar with using your radio for beaconing, you can explore message sending.

Radio Setup

Whether you are a novice or an Elmer, there is a learning curve with sophisticated transceivers like the Yaesu VX-8 series. Guides exist on the Internet to help users set up specific models. The VX-8 can be programmed to provide position information and call sign. It also has customizable beacon settings and alert features that can be activated upon receipt of messages and beacons. See the sidebar for VX-8 links.

The Encounter

I set up my antenna at about a 10° elevation and free from obstructions in preparation for encounters. I found my antenna design does not require absolute laser precision in keeping the antenna aimed, but the best results occur if you can aim by following a printout or program display that predicts the elevation with time. For handheld use, it’s easy to aim. With the bracket I have a counterbalanced assembly adapted for one-handed operation.

I adjust the antenna about once every 15-30 seconds. Adjustments occur more often when the ISS is near overhead. The packet data is broadcast in brief pulses that lasts about ½ second. The sound of an APRS transmission is similar to the handshaking sounds that occur at the beginning of a telephone modem connection. You will hear the



Figure 4 — I took this image on August 10, 2011 from my backyard. In the foreground my tape-measure antenna is set up in position to make contact with the digipeater on the International Space Station, which is traversing the sky leaving a trail in the exposure.

signal attempts coming in for a minute or more before your radio will give you an indication that it is receiving good data.

Keeping your APRS MUTE settings OFF is required for the Yaesu VX-8 family to allow you to hear the first signal coming in, but do not turn your squelch to zero as you might for voice contacts. If you hear the signal degrading audibly it may be time to reorient the antenna. Some radios have musical note pattern tones that give feedback on good acknowledgments and fully received data for beacons, data and your position. I recommend keeping radio settings for audio feedback turned on if equipped. Beacons can be sent manually to minimize interference to other stations transmitting.

Results

With my antenna aimed properly I commonly hear transmissions when the ISS is

more than 1000 miles away. Almost all of these signals are not strong enough for the modem/TNC to interpret and log. Signals robust enough to be decodable began when the ISS was 600-300 miles away during my tests with the antenna I built (see Figure 5). I have seen valid beacons in my log from as far as 1000 miles away on a few occasions.

You should expect an average operating window of about 4 minutes during the best passes (2 minutes advancing plus 2 minutes receding on near overhead encounters). I would get an acknowledgment about 40% of the time with my beacon transmissions during this window. Reasons for not having 100% response probably include local pileups of the ISS receiving packet signals from other sources — especially if others are using more powerful transmitters. It's also possible the return packet acknowledgments are not being received because of the same interference. The farthest I have sent a packet to get an acknowledgment was 700 miles with my 5 W radio. As the ISS wanders away from you, signals will, of course, become more difficult to decode.

When your ISS encounter is over, you can review the APRS beacon data and messages logged in the radio's station listing and APRS message log. You can review this during your encounter, but it may be difficult to press buttons while aiming.

On my radio's station listing, I found the ISS call sign at the time of this writing as RS0ISS-3. Its APRS icon appeared as an airplane. There were no GPS coordinates and it reported no course or altitude. Its position comment appeared as IN SERVICE. The BEACON STATS TXT on its beacon said Atlantis&Nicole heading home. This information may sit for months on the ISS radio without attention, or could be updated at any time.

You can also look at **ARISS.net** or **APRS.fi** to see if your beacon made it to a ground station, which forwarded the information to the Internet. Not all beacons make it to the Internet, so don't be disappointed if you don't see yours. It's also possible for your beacon to make it to one site but not the other. Obviously, if your own call sign appears in your TNC's "head list," that's proof you were successful.

Messaging

Messaging is the second APRS function apart from beaconing that was used on that first flyover. Handheld transceivers and mobile radios with APRS functions can store messages received from others for later review. Reading then composing a message on the fly with just your radio keypad is cumbersome during passes. Many hams attach a computer to send and receive APRS messages. This allows less awkward message composition during the limited time window. *UISS for Windows* is a freeware program that allows you to turn off the radio's APRS function while leaving its TNC on to review and



Figure 5 — The International Space Station is featured in this image photographed by an STS-133 crew member on space shuttle *Discovery* after the station and shuttle began their post-undocking separation.

Additional Information

Doug's YouTube video of an ISS encounter with tips on using a Yaesu VX-8R can be seen at www.youtube.com/watch?v=HdS3EqRooN8. Other online resources helpful for amateur satellite information:

- www.work-sat.com** — probably the best website; updated frequently with tips for working satellites with your handheld transceiver
- amsat.org** — for any Amateur Radio satellite information
- issfanclub.com** — for ISS information and current status of its Amateur Radio from user submitted reports.
- arissat1.com** — for information on the ISS-launched ARISSat-1 satellite
- www.worldwidedx.com/satellites-space-communication-topics** — discussion forum
- groups.yahoo.com/group/VX_8R** — advice on the Yaesu VX-8R radio

send messages via a computer. *AGW Packet Engine* (also freeware) allows a PC to communicate to the radio connected by a serial cable.

You can include a message of a few characters with your beacon by setting it up on your radio. This function may be labeled as STATUS TEXT or BEACON STATS TXT in your settings. Once you are more familiar with reliably working your radio for beaconing, you can explore message sending.

Astro Chats

Now that you have APRS accomplished, you can try voice contacts with the same gear. On rare occasions you may be lucky to hear 145.800 MHz frequency activity. Astronauts use this frequency to chat with other ham operators in their off-duty time or, more commonly, engaged in the middle of a scheduled contact with schoolchildren on the ground.

It surprises me that a small handheld transceiver and a handheld antenna with such small amounts of power can work the ISS. With a little crafting, a little reading and per-

sistence you too can work the satellites.

I would like to acknowledge the following hams for their help in preparing this article: Lisa Cook, KD5PJM; Bob Bruninga, WB4APR; Clint Bradford, K6LCS; Larry Holden, W5MPA; Oscar Staudt, WB5GCX; Clayton Coleman, W5PFG; Erwin van der Haar, PA3EFR; Fred Piering, WD9HNU; Scott Patterson, KC9TVK, and Andy Cunningham, M0HAK.

Photos by Doug Cook, KD5PDN, except as noted.

Dr Doug Cook, KD5PDN, an ARRL member; works as an optometric physician in Guthrie, Oklahoma. He has been licensed since 2001 and is active in Scouting as well as Amateur Radio. He can be reached at 217 Mockingbird Rd, Guthrie, OK 73044, twoeyedox@gmail.com

