The AMSAT® Journal

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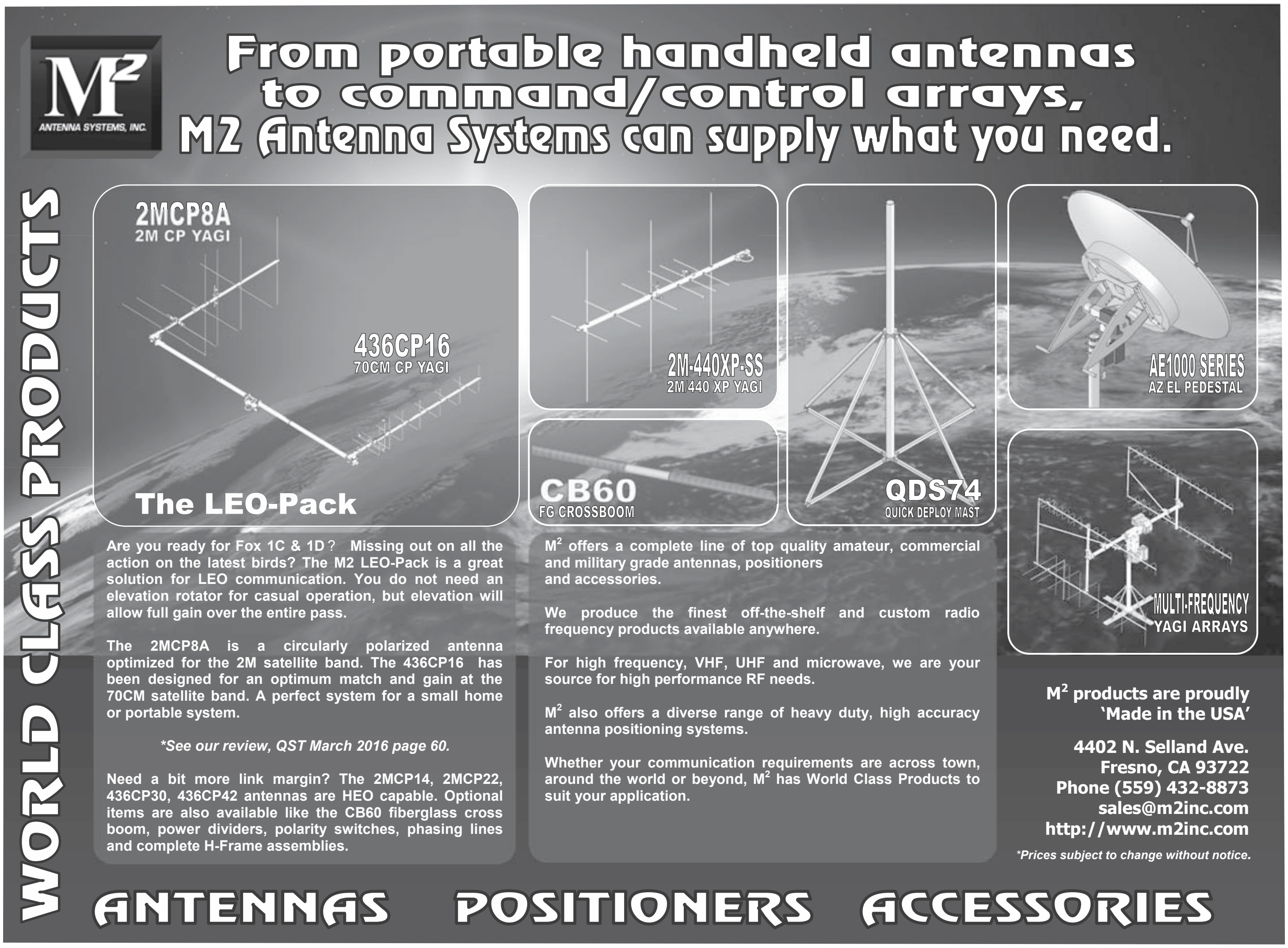
Volume 41, Number 2 — March/April 2018

Tri-Border Activation

in this issue …

Periodicals
POSTAGE PAID
At Kensington, MD
and at additional
mailing offices

AMSAT-NA
10605 Concord St., Suite 304
Kensington, MD 20895-2526



AMSAT Announcements

AMSAT-NA Board of Directors Nomination Notice

It's time to submit nominations for the upcoming AMSAT-NA Board of Directors election. Three directors' terms expire this year: Tom Clark, K3IO; Mark Hammond, N8MH; and Bruce Paige, KK5DO. Also, up to two Alternates may be elected for one-year terms.

A valid nomination requires either one Member Society or five current individual members in good standing to nominate an AMSAT-NA member for Director. Written nominations, consisting of the nominee's name and call, and the nominating individual's names, calls and individual signatures should be mailed to:

AMSAT-NA
10605 Concord St, #304
Kensington, MD 20895-2526.

In addition to traditional submissions of written nominations, which is the preferred method, the intent to nominate someone may be made electronically. This includes e-mail, fax, or electronic image of a petition. Electronic petitions should be sent to martha@amsat.org or faxed to (301) 822-4371.

No matter what means is used, petitions MUST arrive no later than June 15th at the AMSAT-NA office. If the nomination is a traditional written nomination, no other action is required. If it is other than this, i.e., electronic, a verifying traditional written petition MUST be received at the AMSAT-NA office at the above address within 7 days following the close of nominations on June 15th.

ELECTRONIC SUBMISSIONS WITHOUT THIS SECOND, WRITTEN VERIFICATION ARE NOT VALID UNDER THE EXISTING AMSAT-NA BYLAWS.

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.

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The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly (Jan/Feb, Mar/Apr, May/Jun, Jul/Aug, Sep/Oct, Nov/Dec) by AMSAT-NA, 10605 Concord St., Suite 304, Kensington, MD 20895-2526. Telephone: 301-822-4376, fax: 301-822-4371. Periodicals postage paid at Kensington, MD and additional mailing offices.

Postmaster: Send address changes to *The AMSAT Journal*, 10605 Concord St., Suite 304, Kensington, MD 20895-2526. Opinions expressed in The AMSAT Journal are those of the article authors and are not necessarily those of AMSAT-NA.

The AMSAT Journal staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat.org using plain text or word processor files; photos or figures in TIF, GIF or JPG formats. Kindly do not embed graphics or photos in your manuscript. We prefer receiving those as separate files. AMSAT-NA reserves the right to select material for The AMSAT Journal based on suitability of content and space considerations.

Apogee View

Joe Spier, K6WAO
President

This early spring finds AMSAT's AO-85, AO-91, and AO-92 satellites very busy with grid chasers. It would seem that the 2018 ARRL International Grid Chase might be affecting the use of these satellites, but whatever the reason AMSAT members can be proud that we have provided such popular resources for new and experienced satellite operators. Again, I want to acknowledge all the AMSAT members and contributors who helped fund the effort.

And since it is the tax season, who would you rather see your funding go to, the Internal Revenue Service or AMSAT? I choose AMSAT, and I hope you will too. Our GOLF President's Match Challenge raised almost $12k that is matched by our former President's donations. This will give the GOLF-TEE and GOLF-1 projects a great start.

As you will read in this edition of the AMSAT Journal, the requirements of the CubeSat Launch Initiative (CSLI) are explained. So, let's do a little spring cleaning, and by that statement, I mean let's discuss what projects are still waiting for a launch. First off, what constitutes an official AMSAT satellite project is a project proposed to the AMSAT Board of Directors (BOD) and passed with the BOD's vote of approval.

Currently, the BOD approved satellite projects are the Fox and GOLF series. Fox-1Cliff is awaiting a launch currently scheduled before the end of Summer 2018 on Spaceflight's SSO-A mission on board a SpaceX Falcon 9 from Vandenberg AFB, CA. It will carry UHF and L-band uplinks with the VHF downlink plus a Virginia Tech camera experiment. RadFXSat-2 (Fox-1E) is awaiting a launch currently scheduled for no earlier than the end of 2018 on the ELaNa XX mission aboard Virgin Orbit's LauncherOne. It will carry a 30 kHz wide mode V/U linear transponder and Vanderbilt's FinFET radiation experiment. It will also have a 1200 bps BPSK telemetry beacon.

The 3U GOLF-TEE is beginning spacecraft development, as is GOLF-1. AMSAT also has development programs that run under the Engineering, Education, and Human Spaceflight departments. These programs are where no specific spacecraft development has been BOD approved.

In Engineering, many of the non-specific programs in ASCENT (Advanced Satellite Communications and Exploration of New Technology) have now been assigned to the GOLF projects. The 5 GHz and 10 GHz Ground Terminal program was to design and test a functional Ground Terminal for an eventual Virginia Tech proposed Phase 4 spacecraft. This Phase 4 effort was to be led and funded by Virginia Tech with assistance provided by select AMSAT engineering personnel working separately under Virginia Tech's program. Virginia Tech will likely make an updated announcement on this effort by late May 2018.

The Education Department is working on a CubeSat Simulator program, while Human Spaceflight is continuing to complete the next phase of safety design review testing on the Multi-Voltage Power Supply (MVPS) for Amateur Radio on the International Space Station (ARISS). Once this expensive testing is completed, ARISS may then schedule the launch to the ISS of the MVPS along with the new Kenwood TH-D710 radios. Of course, your contributions to ARISS are needed to assist in funding these tests.

AMSAT also had approved a program to assist developing a Phase 5 spacecraft for the NASA Lunar Cube Quest Challenge. AMSAT had partnered with Ragnarök and their Heimdallr 6U proposal which unfortunately was not selected as one of the three finalists. So AMSAT and Ragnarök are currently under negotiations to discover what viable components may be applied to the GOLF missions.

As your President, I am continuing to work on a policy for Export Administration Regulations/International Traffic in Arms Regulations (EAR/ITAR), and I hope to have an explanation in next edition of *The AMSAT Journal*. I have had some great input from the engineers who the policy directly affects, and the policy is currently undergoing a professional review.

Under the guidance of Phil Smith, W1EME, AMSAT is preparing for the May 18-20, 2018, Hamvention that will be at the Greene County Fairgrounds in Xenia, OH. Our commercial exhibit space includes eight commercial booths, which gives us additional room to highlight our engineering programs, membership Q/A area, and ARISS. Our booth location will be in the first aisle in Building One just as it was in 2017. AMSAT will occupy the entire aisle 1 area (booths 1007-1010 and 1107-1110). This arrangement provides not only more space but allows us to tailor the area to our needs without potential interference from other vendors.

Just as important, the satellite demo area (led by Paul Stoetzer, N8HM) will be located just outside Building One on the same side of the building as our exhibit space. In essence, the demo area will be sharing the front wall with the AMSAT exhibit area, making it easier to direct people to demos and providing potential opportunities for improved support services for the satellite demo team.

Our social activities will continue as we've done during previous Hamventions. Activities include an informal social get together at Ticket's Pub in Fairborn on Thursday night. The annual AMSAT/TAPR (or TAPR/AMSAT) dinner takes place at the Kohler Presidential Center Friday evening, as in the past. AMSAT is to provide the banquet speaker, and we are pleased to announce that Jeri Ellsworth, AI6TK, has agreed to be our speaker.

Jeri will present her innovative ideas and adventures in Amateur Radio. Jeri is an entrepreneur, self-taught engineer, and autodidactic computer chip designer and inventor. In 2016, she passed all three amateur radio exams, earned her Amatur Extra license, and received the AI6TK callsign, launching her adventures in Amateur Radio.

She was featured in the January 2017 issue of *QST* and in YouTube videos from Quartzfest earlier this year. Jeri has been given a fairly free hand to speak on whatever topic she wishes (as long as it's amateur radio, somewhat).

Tickets ($37 each) maybe be purchased from the AMSAT Store. The banquet ticket purchase deadline is Tuesday, May 15. Banquet tickets must be purchased in advance and will not be sold at the AMSAT booth. No tickets may be picked up at the AMSAT booth. Tickets purchased on-line will be maintained on a list with check-in at the door of the banquet center. Seating is limited to the number of meals reserved with the Kohler caterers based on the number of tickets sold by the deadline.

An AMSAT Forum is scheduled Saturday morning. Our moderator is AMSAT Treasurer Keith Baker, KB1SF/VA3KSF. Our Forum speaker/presentation list will be (me) the AMSAT President Joe Spier, K6WAO, AMSAT Vice-President for Engineering, Jerry Buxton, N0JY, and AMSAT Vice-President for Human Spaceflight, Frank Bauer, KA3HDO. It will be a jam-packed 60 minutes. That's right, we are limited to 60 minutes this year, so I will limit my presentation/update, so everyone may get the exciting news from the AMSAT Engineering and ARISS Executive Team Leaders.

AMSAT will offer the latest materials at the booth this year, including a 2018 edition of *Getting Started with Amateur Satellites*, as well as the latest in "satellite fashions." We'll once again provide a "Beginner's Corner" where we will answer questions about amateur radio satellites and communications.

Hamvention is amateur radio's premier gathering in North America. AMSAT's presence is important because it not only provides a venue to interact with our members and those interested in amateur radio satellites, but it also provides an opportunity to engage those that may not currently be active with satellites. Our mantra is "Keeping Amateur Radio In Space™," but we also need to be diligent about that mantra in front of thousands of amateurs who attend Hamvention. Our Hamvention presence builds awareness, generates revenue, and lays the foundation for future support.

So if you go, you'll be there with thirty thousand of your closest friends. There is truly nothing like it, so I hope to have seen you there!

Board Creates New AMSAT Ambassadors Program

AMSAT's Field Operations program has consisted of regional volunteers ("Area Coordinators") who perform activities such as attending hamfests, conducting satellite demonstrations, and one-on-one mentoring on an as-needed basis. This program has served AMSAT well for many years, but its future growth may be hindered because the Internet has become many radio amateurs' primary source of knowledge.

To revitalize the field operations program, the AMSAT Board of Trustees has decided to make several changes. First, the program will operate under a new name, "The AMSAT Ambassador" program. This name reflects that those who participate represent AMSAT, the organization, and are acting on its behalf as emissaries. Second, the program will no longer operate on a regionalized basis of geographic "areas" because much mentoring today is conducted via online means.

Third, the goals of the new AMSAT Ambassador program will be as follows:

- Maintain a pool of volunteers who can demonstrate a current, working knowledge of Orbiting Satellites Carrying Amateur Radio (OSCAR) to promote AMSAT
- Represent AMSAT by sharing enthusiasm for Amateur Radio in Space with others
- Share AMSAT's vision and mission, whether at in-person events, practical demonstrations, online, or in written communications
- Connect volunteers with potential members, both in-person and online, in a manner encouraging their affiliation by membership in AMSAT
- Offer personal mentoring and coaching to new enthusiasts either in-person or via online means such as email, chat, and social media, and
- Connect members and potential enthusiasts with proper resources at AMSAT when they seek more knowledge, volunteer to serve, or have concerns about the organization.

The position of volunteer "AMSAT Ambassador" requires:

(1) Agreement and active participation in all stated goals above, and
(2) Generating one annual status communication to the Board of Directors, via email, stating the activities the Ambassador performed over the year and describing how the Ambassador shared AMSAT's vision and mission.

The AMSAT President will appoint the "Director, AMSAT Ambassadors" with the following responsibilities:

- Maintain the list of active Ambassadors, verify each has sent annual status reports as required, and post the list on AMSAT's website.
- Maintain a current "Introduction to AMSAT" presentation available on the AMSAT website to be updated no less than twice annually, and whenever new satellites come into service or older satellites are no longer operational.
- Develop and promote a basic checklist for Ambassadors to use at events, and
- Administer or designate administrators for the Ambassador mailing list.
- Act as liaison between requests from Ambassadors to AMSAT Officers, Board of Directors, and other volunteers on an as-needed basis.
- Perform other AMSAT Ambassador program-related duties as requested by the President or Executive Vice President.

Initially, the AMSAT Ambassador program will be administered by the AMSAT Corporate Secretary, Clayton Coleman, W5PFG. He can be reached at **w5pfg@amsat.org**.

Smile for AMSAT at Amazon.com

When making purchases from Amazon, you can select a charity and Amazon will donate .5% of a qualified purchase towards that charity. Select smile.amazon.com when making your Amazon purchases and make Radio Amateur Satellite Corporation (AMSAT) your chosen charity.

Having selected a charity, when you go to amazon.com, you will be prompted to go to smile.amazon.com. However, you can put everything you want in your cart at the original amazon.com site, then leave the site and go to smile.amazon.com and all your items will still be in your cart.

Engineering Update

Jerry Buxton, N0JY
Vice President, Engineering

GOLF Is On The Fairway

On March 2, 2018, NASA announced the Ninth Round of Candidates for CubeSat Space Missions. AMSAT was among the satellites chosen in this CubeSat Launch Initiative (CSLI), and I am pleased to say that both of our submissions, GOLF-TEE and GOLF-1, were selected. The launch opportunities are aboard missions in the 2019-2021 period.

No launches have been selected or designated yet. AMSAT must enter into a Cooperative Research and Development Agreement (CRADA) with NASA for each mission, and launch opportunities will be presented to us as NASA works through the list of available missions and their suitability to the orbit requested by the sponsoring organization.
GOLF-TEE (Greater Orbit, Larger Footprint – Technology Exploration Environment) was submitted with a primary focus on technology development, the first AMSAT CubeSat CSLI targeting this area of the NASA Strategic Plan. The purpose of GOLF-TEE is rapid development and deployment of technology that AMSAT needs to have in its repertoire to fly successful higher orbit missions including the HEO (Highly Elliptical Orbit) missions that are desired by many. GOLF-TEE is expected to bring us a variety of knowledge and experience that includes:

- Attitude Determination and Control (ADAC) hardware and software
- Deployable solar panels array development and experience
- Software Defined Radio (SDR) capability and knowledge for many bands, focusing on 5 and 10 GHz ("Five and Dime") capability
- Development and understanding of radiation tolerant IHU (Internal Housekeeping Unit a.k.a. flight computer) hardware and software
- Development of a bus with the capability to support various educational experiments as we have been doing with the Fox-1 Program.

All of the GOLF series CubeSats will be 3U, meaning the size of the CubeSat is approximately the equivalent of three Fox-1 1U CubeSats in a stack. The larger size allows for more power production and storage capability and more area for antennas in addition to the obvious "more room inside" for avionics including radios and experiments.

We expect GOLF-TEE to be ready for delivery to NASA for integration in 4Q 2019, which means that a launch as early as 4Q 2019 could be possible if NASA's missions line up with our timeline and orbit desires. GOLF-1 will be the first official "General Availability" GOLF CubeSat and is expected to contain and build upon the critical systems being developed for and tested in GOLF-TEE.

The ADAC, solar panels, and power are the critical and base elements of GOLF-1. The development of the GOLF-TEE radios and IHU will lead to similar and more robust systems in GOLF-1. GOLF-1 will host two educational experiments; a radiation effects experiment from our longtime partner Vanderbilt University and a camera to be used for meteorological observation and experimentation being provided by Albuquerque Public Schools, designed and built by Valley High School in cooperation with Virginia Tech.

GOLF-1 is also intended to be the first to live up to the name/acronym for the GOLF Program, Greater Orbit, Larger Footprint. AMSAT requested an orbit of 1300 km (bounded by an acceptable range of 1000-1400 km) and an inclination similar to that of AO-85 (Fox-1A) with the intention that GOLF-1 will supplement AO-7 and FO-29 in QSO distance capability. That aspect of the GOLF project and CSLI proposal that AMSAT submitted has been kept internal prior to this Journal column, so you are the first to hear the announcement!

This leads right into the opportunity for a reminder that your donations help and are needed to make these launches a reality. Many desire a "return to HEO," and that will cost much more to achieve than any of our prior CubeSat missions including GOLF-TEE and GOLF-1. With the CSLI round in which GOLF-TEE and GOLF-1 were submitted, NASA placed a funding cap of $300,000 per mission. That means that the "free launch" to LEO can still be achieved for up to a 3U CubeSat, but our desires to go higher into MEO and HEO will require AMSAT to pay the balance in launch costs over $300,000. For a ballpark figure based on "MSRP" for launch services today, that means that a 3U to Geosynchronous Transfer Orbit (GTO, which is in effect a HEO) may cost up to $600,000 just to cover the launch costs beyond any CSLI that we may be blessed to be awarded. Please keep that in mind.

General GOLF-TEE design was already underway while awaiting the CSLI announcement but has now been formally advanced with the appointment of a Project Management Team and Systems Engineer, and is expanding through the other organizational and resource needs to enable our engineers to be successful in these projects. Rather than one Project Manager, because of the complexity (time involved) and all volunteer staffing of any engineering project, we determined that a small team of project managers would be more stable in providing the attention and leadership needed. This will avoid coverage gaps that we all experience in attending to the matters that come first before our hobby and lapses/loss of knowledge and expertise if volunteers come and go as is also to be expected.

The GOLF-TEE/GOLF-1 Project Management Team are:

- Bill Reed, NX5R
- Jonathan Brandenburg, KF5IDY
- Tom McDermott, N5EG
- Yours truly as the voice of experience with AMSAT's CubeSat projects (not open for debate!)

The GOLF-TEE/GOLF-1 Systems Engineer is Eric Skoog, K1TVV who is also Systems Engineer in the Fox-1 program. A number of engineers that you may know well or have heard of are "in" on the GOLF projects and bring expertise and experience from both the Fox-1 program and ASCENT, along with new volunteers joining. If you are interested in devoting some time to seeing the GOLF projects on orbit, please visit the AMSAT Engineering volunteer page at www.amsat.org/contact-amsat-engineering. There is and will be much more to say, so stay tuned for the next issue!

Fox-1 Update

We have been busy providing final paperwork to Spaceflight for Fox-1Cliff, as Spaceflight moves toward the launch of their SSO-A mission in the summer of this year. While Fox-1Cliff had been closed out for the original launch, changing launch vehicles always involves changes in requirements and environment. As a result, both Fox-1D and Fox-1Cliff must undergo a process to determine whether (1) the existing requirement and test values that were met will be approved for the new launch vehicle, or (2) more information must be provided for the new launch.

RadFxSat-2/Fox-1E continues on schedule for the ELaNa XX mission with a launch expected this summer as well. As of March 12, the final flight model (FM) is being built, and I expect to see it in Fox Labs in a few days to undergo the testing and qualification that are required both for launch and to satisfy us that she is working properly.

Once testing and qualification are complete, RadFxSat-2 will be taken to NTS in Boxborough, MA for final environmental testing and thermal vacuum bakeout. By the end of April, we expect to be ready and waiting for delivery and integration.

If you are thinking about it but have not yet tried Mode L on AO-92, I encourage you to try it. We (Engineering) are just as pleased as punch about the sensitivity of the receiver and overall performance of the L/v mode system.

Neal Reasoner, KB5ERY, SK

I am sad to share the news that one of our AMSAT Engineering volunteers, Neal Reasoner, KB5ERY, passed away in February. Neal was a relatively new member of the team and offered and brought his expertise in FPGA programming to ASCENT, and ultimately to GOLF but for a short while. He worked on the SDR design that we had in mind for GOLF and beyond. Neal lived in Austin, Texas, and found out about our work through his father Harold Reasoner, K5SKX, of Fort Worth, who introduced us. Thank you for volunteering and being a part of our team, Neal. SK de N0JY.

AMSAT Field Day 2018 Rules

Bruce Paige, KK5DO

It's that time of year again, summer and Field Day! Each year the American Radio Relay League (ARRL) sponsors Field Day as a "picnic, a campout, practice for emergencies, an informal contest and, most of all, FUN!" The event takes place on the fourth weekend of June. For 2018, the event takes place during a 27-hour period from 1800 UTC on Saturday, June 23, 2018, through 2100 UTC on Sunday, June 24, 2018. Those who set up before 1800 UTC on June 23 can operate only 24 hours. The Radio Amateur Satellite Corporation (AMSAT) promotes its own version of Field Day for operation via the amateur satellites, held concurrently with the ARRL event.

This year should be easier than many past years because we have more than 10 transponders and repeaters available. Users should check the AMSAT status page at **www.amsat.org/status/** and the pages at **www.amsat.org/?page_id=177** for satellites available in the weeks leading up to Field Day. To reduce the amount of time to research each satellite, see the current FM satellite table at **www.amsat.org/?page_id=501**2 and the current linear satellite table at www.amsat.org/?page_id=5033.

If you are considering ONLY the FM voice satellites, there are SO-50, AO-85, AO-91, AO-92 and possibly PicSat. It might be easier this year to make that one FM contact for the ARRL bonus points with so many FM birds. The congestion on FM LEO satellites is always so intense that we must continue to limit their use to one QSO per FM satellite. This includes the International Space Station (ISS). You will be allowed one QSO if the ISS is operating voice.

A suggestion from past field days was to allow a control station to coordinate contacts on the FM satellites. Nothing in the rules would prohibit this, as it represents a single station working multiple QSOs. If a station were to act as a control station and give QSOs to every other field day station, the control station would still only be allowed to turn in one QSO per FM satellite while the other station would be able to submit one QSO.

The format for the message exchange on the ISS or other digital packet satellite is an unproto packet to the other station (3-way exchange required) with all the same information as normally exchanged for ARRL Field Day, such as:

W6NWG de KK5DO 2A STX
KK5DO de W6NWG QSL 5A SDG
W6NWG de KK5DO QSL

If you have worked the satellites on Field Day in recent years, you may have noticed a lot of good contacts can be made on some of the less-populated, LEO satellites like FO-29, AO-7, AO-73, NAYIF-1 or the XW satellites. During Field Day, the transponders come alive like 20 meters on a weekend. The good news is that the transponders on these satellites will support multiple simultaneous contacts. The bad news is that you can't use FM, just low duty-cycle modes like SSB and CW.

THE 2018 AMSAT FIELD DAY RULES

The AMSAT Field Day 2018 event is open to all amateur radio operators. Amateurs are to use the exchange as specified in ARRL rules for Field Day. The AMSAT competition is intended to encourage the use of all amateur satellites, both analog and digital. Note that no points will be credited for any contacts beyond the ONE allowed via each single-channel FM satellite. Operators are encouraged not to make any extra contacts via these satellites (e.g., SO-50). CW contacts and digital contacts are worth three points as outlined below.

1. Analog Transponders

ARRL rules apply, except:

Each phone, CW, and digital segment ON EACH SATELLITE TRANSPONDER is considered to be a separate band.

CW and digital (RTTY, PSK-31, etc.) contacts count THREE points each.

Stations may only count one completed QSO on any single channel FM satellite. If a satellite has multiple modes such as V/u and L/s modes both turned on, one contact, each is allowed. If the PBBS is on - see Pacsats below, ISS (one phone and one digital), Contacts with the ISS crew will count for one contact if they are active. PCSat (I, II, etc.) (one digital),

The use of more than one transmitter at the same time on a single satellite transponder is prohibited.

2. Digital Transponders

We have only APRS digipeaters and 10 m to 70cm PSK transponders (see Bob Bruninga's article in the March/April 2016 issue of *The AMSAT Journal*).

Satellite digipeat QSO's and APRS short-message contacts are worth three points each but must be complete verified two-way exchanges. The one contact per FM satellite is not applied to digital transponders.

The use of LO-90 to make a voice up and digital down contact will count as a digital contact for 3 points.

The use of terrestrial gateway stations or internet gateways (i.e., EchoLink, IRLP, etc.) to uplink/downlink is not allowed.

For the Pacsats (FalconSat-3) or Store-and-Forward' hamsats, each satellite is considered a separate band. Do not post "CQ" messages. Simply upload ONE greeting message to each satellite, and download as many greeting messages as possible from each satellite. The subject of the uploaded file should be posted as Field Day Greetings, addressed to ALL. The purpose of this portion of the competition is to demonstrate digital satellite communications to other Field Day participants and observers. Do not reply to the Field Day Greetings addressed to ALL.

The following uploads and downloads count as three-point digital contacts:

(a) Upload of a satellite Field Day Greetings file (one per satellite).
(b) Download of Satellite Field Day Greetings files posted by other stations. Downloads of non-Field Day files or messages not addressed to ALL are not to be counted for the event. Save DIR listings and message files for later "proof of contact."

Please note AMSAT uploaded messages do not count for QSO points under the ARRL rules.

Sample Satellite Field Day Greetings File:

Greetings from W5MSQ Field Day Satellite station near Katy, Texas, EL-29, with 20 participants, operating class 2A, in the AMSAT-Houston group with the Houston Amateur Television Society and the Houston QRP club. All the best and 73!

Note that the message stated the call, name of the group, operating class, where they were located (the grid square would be helpful) and how many operators were in attendance.

3. Operating Class

Stations operating portable and using emergency power (as per ARRL Field Day rules) are in a separate operating class from those at home connected to commercial power. On the report form simply check off Emergency or Commercial for the Power Source and be sure to specify your ARRL operating class (2A, 1C, etc.).

AND FINALLY...

The Satellite Summary Sheet should be used for submission of the AMSAT Field Day competition and be received by KK5DO (email or postal mail) by 11:59 P.M. CDT, Monday, July 9, 2018. This is earlier than the due date for the ARRL submissions. The preferred method for submitting your log is via e-mail to k**k5do@amsat.org** or **kk5do@arrl.net**.

You may also use the postal service but give plenty of time for your results to arrive by the submission date. Add photographs or other interesting information that can be used in an article for The AMSAT Journal.

You will receive an email back (within one or two days) from me when I receive your email submission. If you do not receive a confirmation message, then I have not received your submission. Try sending it again or send it to my other email address. If mailing your submission, the address is:

Bruce Paige, KK5DO
Director of Awards and Contests
PO Box 1598
Porter, TX 77365-1598.

Certificates will be awarded at the AMSAT General Meeting and Space Symposium in the fall of 2018 for the first-place emergency power/portable station, as well as second and third place portable/emergency operation, in addition to the first-place home station running on emergency power. A station submitting high, award-winning scores will be requested to send in dupe sheets for analog contacts and message listings for digital downloads.

You may have multiple rig difficulties, antenna failures, computer glitches, generator disasters, tropical storms, and there may even be satellite problems, but the goal is to test your ability to operate in an emergency situation. Try different gear. Demonstrate satellite operations to hams that don't even know the hamsats exist. Test your equipment. Avoid making more than ONE voice contact via the FM-only hamsats or the ISS, and enjoy the event!

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Here is an example of the form:

AMSAT Satellite Summary Sheet - 2018

Satellite and number of Voice QSOs
AO-27 1 (example)

Satellite and number of CW/RTTY/
PSK31 etc. QSO's
AO-07 5 (example)

Satellite and Up/Downloads
UO-11 3 (example)

Score Calculation	
Total Voice QSOs	x 1 =
Total CW/RTTY/PSK31 QSOs	x 3 =
Total Up/Downloads	x 3 =
Grand Total	=

Please provide the following information

Your Field Day Callsign

Your Group Name

ARRL Field Day Classification
ARRL Section
Power Source (Select 1)
    Emergency
    Commercial

Your name and home call

Home address

Any Comments

ASCENT Ground and Satellite Demonstration

Ray Roberge, WA1CYB
Howie DeFelice, AB2S

Amateur radio operators have not had a high earth orbit (HEO) satellite since the untimely loss of AO-40 in 2004. A lot has changed in the satellite industry since then. It took a multi-national team six years to design and build AO-40 at the cost of several million dollars. It weighed in at 632 kg, was about 2 meters across and could generate up to 600 W of solar power. In the current environment, the most likely affordable launches will be 3U CubeSats that are about 30 cm across at the longest dimension, have a mass of about 9 kg and might be able to generate 50 W of solar power on a good day. Add to this the government mandated restrictions that all but eliminate international cooperation and the picture looks pretty bleak.

AMSAT needed a way to take all these lemons and mix up a big batch of lemonade. So, AMSAT formed Advanced Satellite Communications and Exploration of New Technology (ASCENT).

ASCENT'S ultimate goal is to place more capable satellites into higher orbits that give more users more access for longer periods of time. This objective requires multiple disciplines working on many fronts to uncover and capitalize on not only new technology but new launch opportunities and new strategic partnerships with industry and academia as well.

One of the first technologies the team turned to was software defined radio (SDR) and digital modulation. As with most new things, this was more evolutionary than revolutionary. ARISSat already used SDR techniques in its transponder, and much of this technology was used and improved in the Fox series of satellites. To get to a multi-user transponder that can accommodate hundreds of users within a very small footprint with limited power requires a big step up in complexity in terms of digital signal processing capabilities and spacecraft support systems like power generation, attitude control and propulsion. Fortunately, we don't need to make this giant leap in one step.

This paper proposes the first step with a new type of transponder that supports multiple linear and non-linear (FM) conversations simultaneously in a single transponder. The downlink will be in X-band (10.45 GHz.). The demonstration ground terminal will be low-cost and incorporate real-time Doppler compensation.

Current Focus Goals

- C-band uplink, X-band downlink (Five-and-Dime)
- Provide frequency/time-locking capability for the ground station
- Utilize SDR technology to maximize flexibility to experiment and modify operation
- Optimize satellite architecture to minimize ground station costs
- Provide output maximum power weighting for the downlink to prevent satellite capture
- UHF/VHF/L-band/S-band/HF optional uplinks
- Provide a digital downlink of satellite data
- Provide a digital downlink of ID, time stamp, location (e.g., GPS/grid square) and uploaded TLE
- Provide for a DVB-S2 input and output when available
- Build in redundant paths where feasible
- Provide multiple digital downlink paths
- Provide multiple voice downlink paths with different modulation types
- Provide a multi-channel in/single-channel out for contact initiation and/or emergency channel
- Provide a controlled ham band scanner survey downlink capability

Approach

- Build and demonstrate an example ground and satellite system that gives the user a sense of what a modern satellite system might look like
- Concentrate on the system, not the implementation
- Incorporate the latest technology that is available and cost-effective
- Use hardware and software that is identical to or mimics planned future systems
- Make the communication architecture programmable to facilitate experimentation and optimization
- Use commercial off-the-shelf (COTS) SDRs likely to be used to facilitate early launch opportunities

The System

- One laptop computer operating as the satellite processor and display, connected to two SDR receiver channels and one downlink transmit channel (Figure 1)
- One laptop computer operating as the ground station computer and display. Connected to two SDR receiver channels and one uplink transmit channel. One of the receiver channels is strictly for demonstration of a local input, in place of a microphone.

Satellite Communication Processing

- The requirement is that all ground stations have locked onto the satellite's beacon and all transmit uplinks will have zero Doppler shift at the satellite's input
- The satellite transmits both a CW beacon and a phase modulated pulse at one pulse per second
- All receivers (two in this case) are translated to wideband baseband for channel separation
- Input frequencies are shifted and filtered according to the programmable configuration plan
- Each segment of the spectrum (channel) is handled in accordance with its intended modulation use
- All channels have a separate filtering, AGC and squelch circuitry set in accordance with its intended modulation use. AGC timing and squelch thresholds are different per mode.
- Channels can be either linear, regenerated or cross-modulated (e.g., NBFM in, USB out)
- Channel content can be analog or digital
- Control ground station can upload a new channel allocation and processing

Figure 2 shows simplified example channel processing

Figure 2 –Satellite Channel Processing Examples

Why Programmable?

- Because we can! That's the beauty of SDR. We can launch with one band plan and set of mode possibilities, and later reconfigure the satellite for new modes and band plans.
- We can refocus the satellite resources to assist in emergency situations.
- For instance, digital messaging may be more important than voice. Perhaps

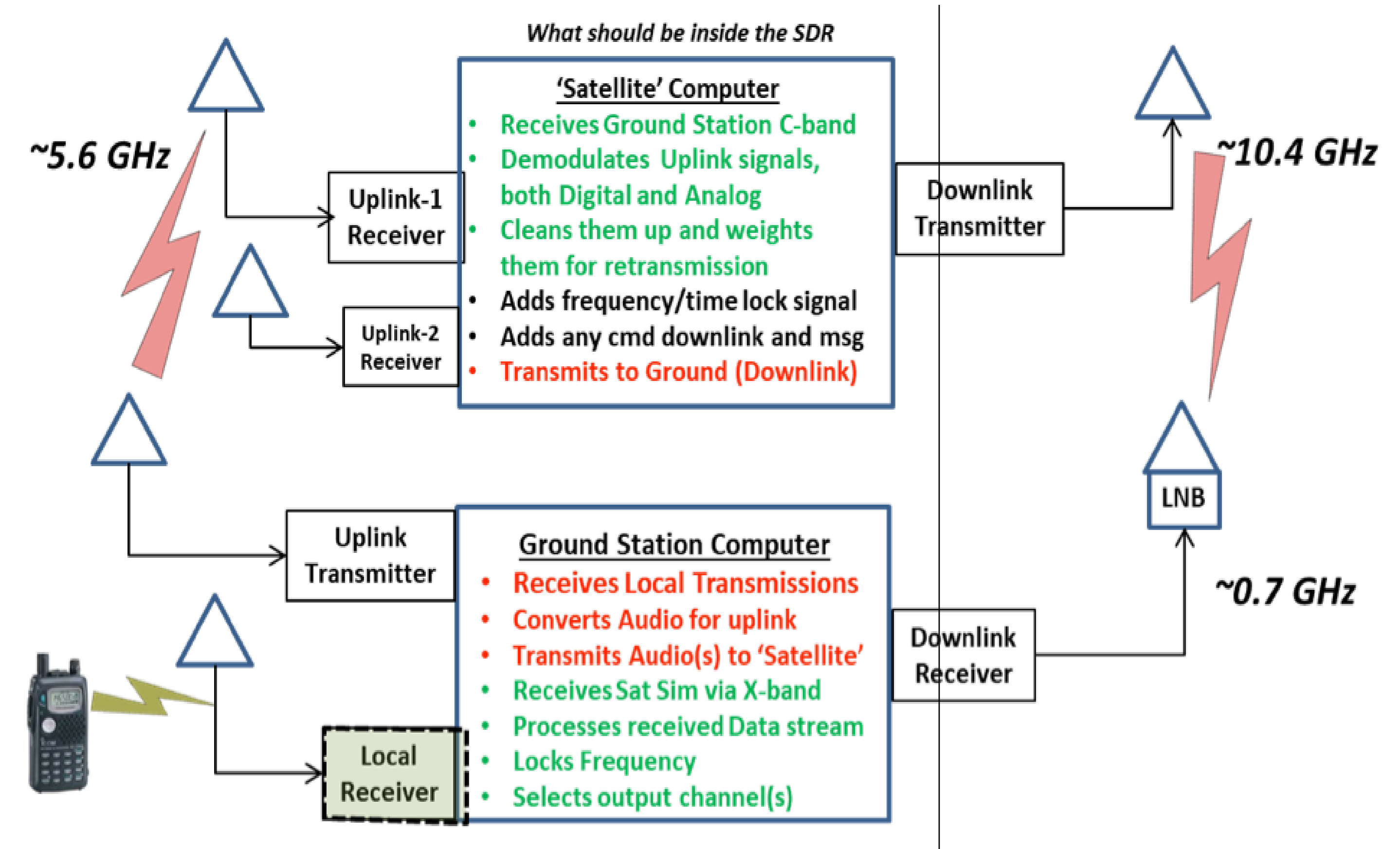

Figure 1 - Basic Communications System Functions.

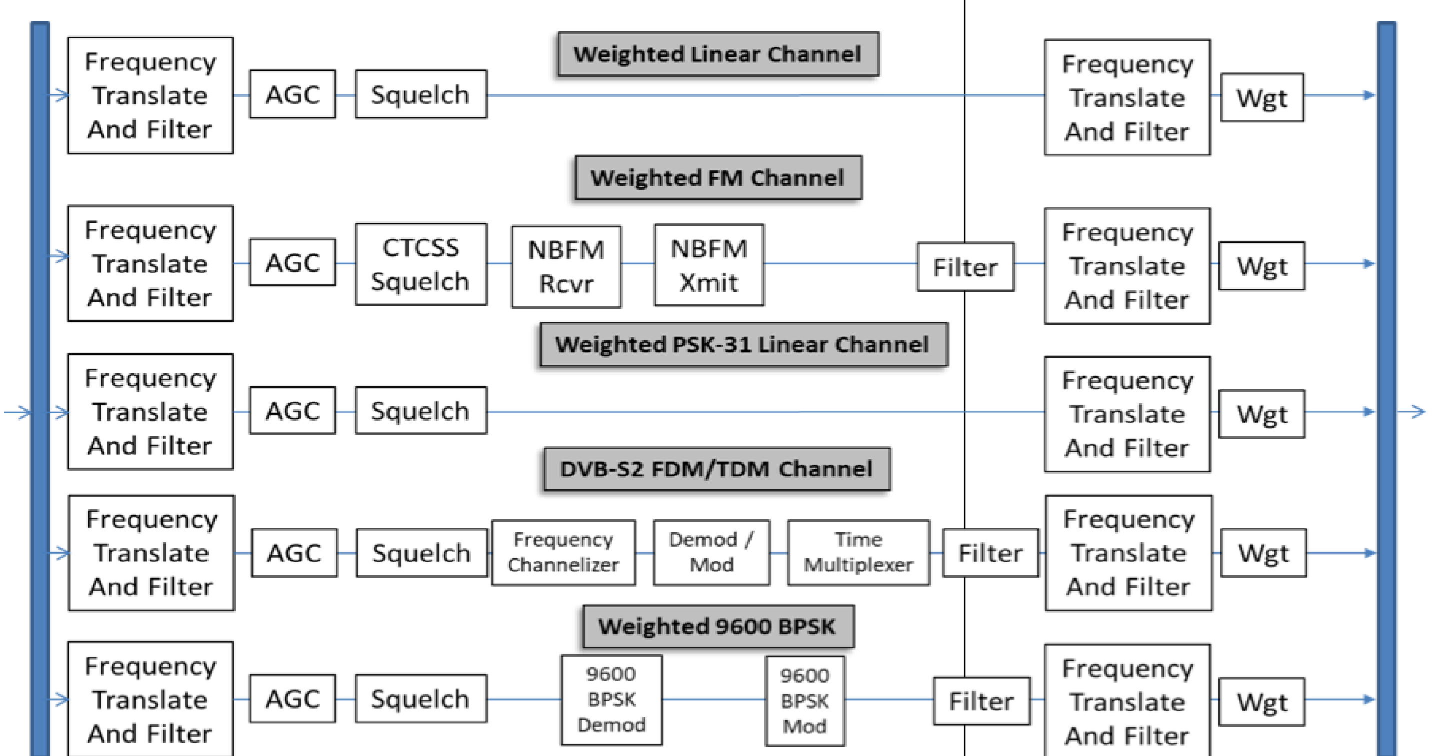

Figure 2 - Basic Communications System Functions.

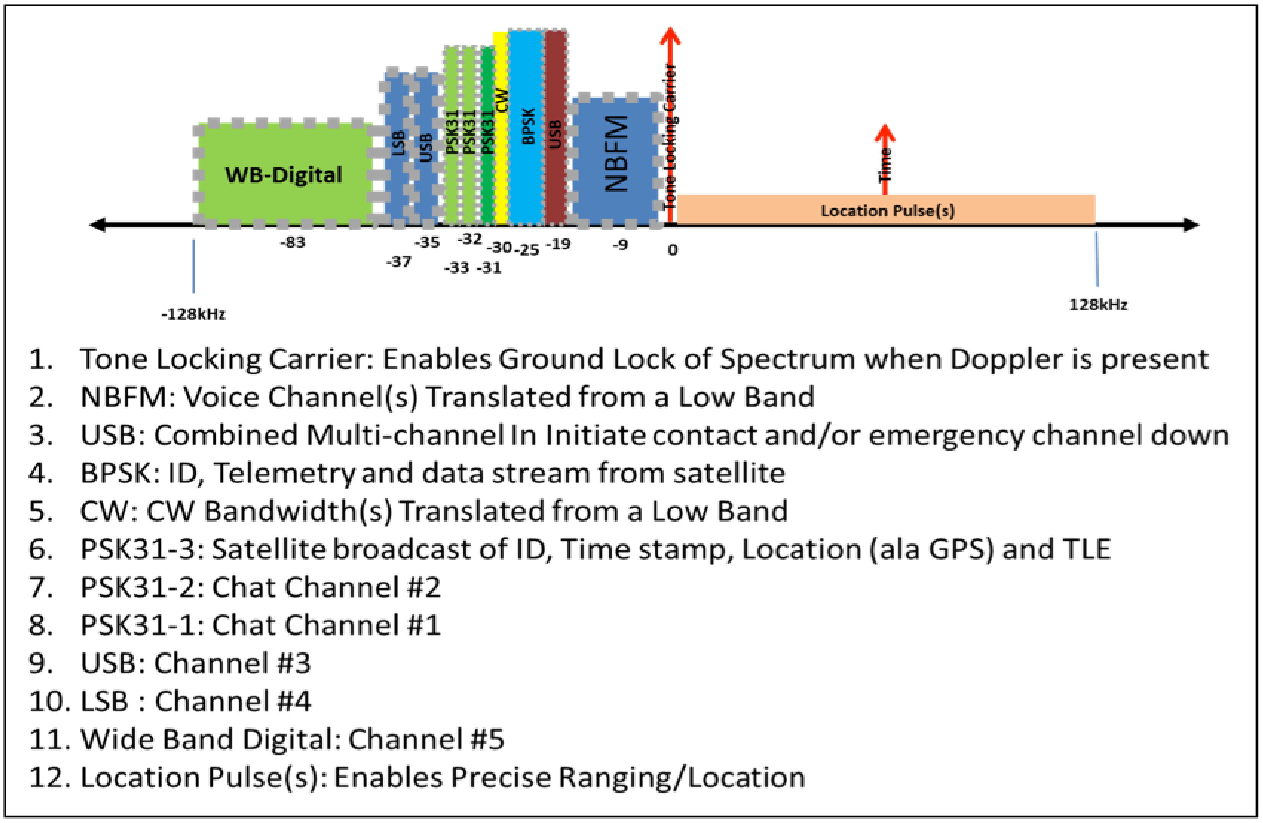

Figure 3 – Demonstration Downlink Frequency Band Plan- Arbitrary Peak Weighting.

Figure 4 -2 Satellite receivers enabled, one tuned to 2 meters, the second tuned to an ATSC HD pilot tone.

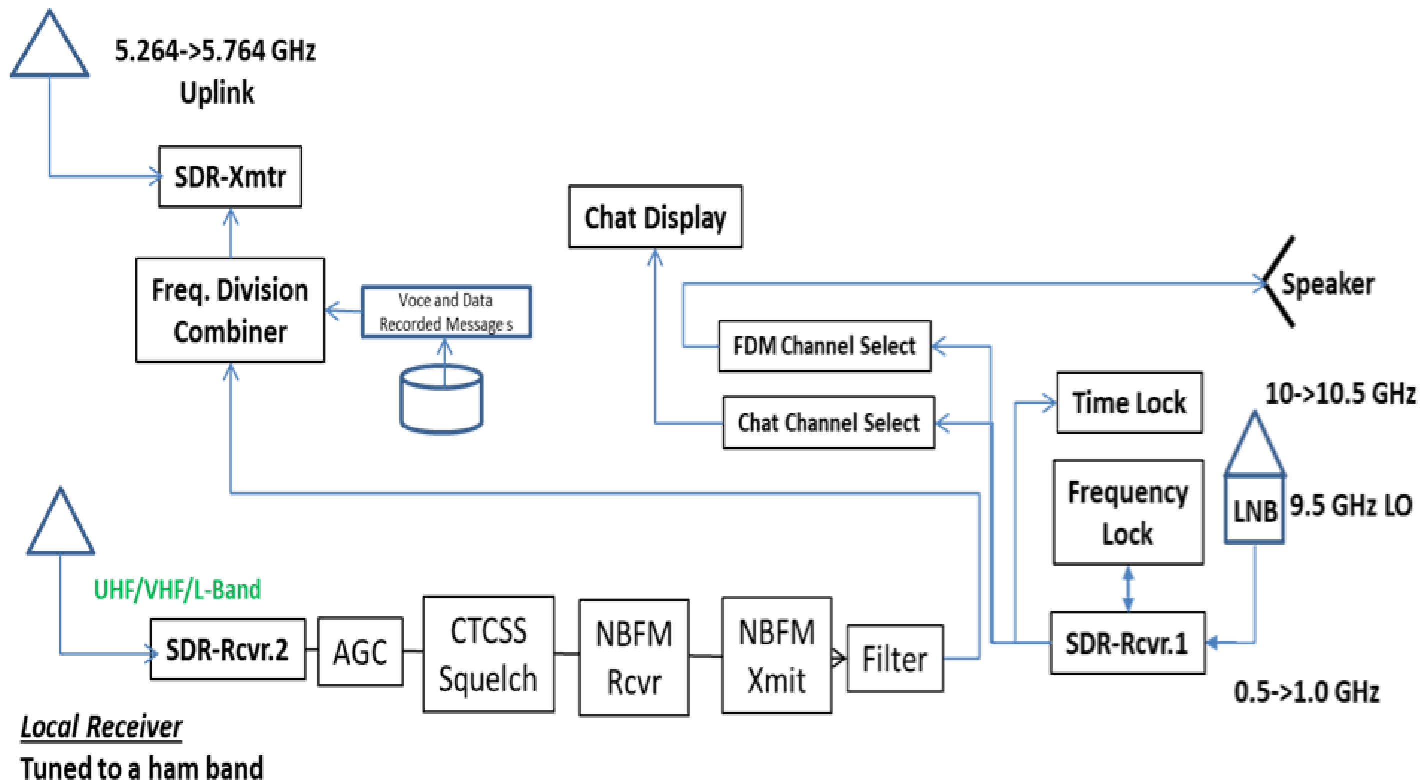

Figure 5 – Ground Station.

a chat with PSK31 should be the highest priority and weighting to get the real-time status message through with minimal ground equipment, etc.

- Programmability enables a common satellite method that can be used and programmed differently before and after launch
- A programmable approach enables new possibilities for experimenting with cross-band and cross-modulation type communication.
- Selected receive frequencies can be polled on a specific schedule for emergency use.

Other Experimental Possibilities

The second receiver can be tasked to do other functions while the main one continues. Possibilities include: (1) conducting an amateur frequency survey (multi-bands) or multiple frequency inputs on different bands with common output band channel (cross-band input); (2) sharing aperture antenna steering or automatic logging of satellite users/peak signal level/vs satellite location or very weak satellite transmitter power beacon experiments (no power amplifier, straight SDR power); or (3) even more satellite input frequency receivers (one chip for each two frequency bands) or harmonic beacons for frequencies above X-band — endless possibilities!

What We Can Build Now

Everything, although it may not work just yet. We have provided the framework to simulate the satellite and ground nodes using laptops for the processor, as opposed to the SDR's processor. Because the ETTUS SDR runs GNU Radio as does the laptop, its porting should be an easier step than coding its FPGA directly.

The Demo System

Figure 3 shows the selected band plan to demonstrate the concept. It offers a dozen functions covering a potential bandwidth of +/- 128 kHz. The satellite's output power is set by the combination of the dozen functions. Some functions, like NBFM, have a constant peak power while others like lower sideband have an average power much lower than its peak to equalize the energy used. One can enhance the LSB at the expense of the NBFM. Also, the narrow band PSK31 channels are assumed to be higher priority, so they are given more of the output energy.

With the entire band plan predicated on receiving the tone-locking carrier, it receives the most power allocation. The location and one pulse per second timing receive less peak power because of the high processing gain.

Figure 4 shows the satellite control program output spectrum when one satellite SDR receiver was tuned to 2 meters and the second one was tuned to an ATSC TV station calibration frequency. Every second frequency block allocation was attenuated so as to see the band plan. The lower right area shows how one could reallocate the blocks, weighting and frequency offsets and filter bandwidths.

The Ground Station

Figure 5 shows the functional diagram of the barebones demonstration ground station. A second SDR (RTL-Dongle) was added so as to have a local input (instead of a microphone) that people could utilize. The ground station has recorded uplink messages internally generated. The received signal consists of a chat channel window and a single audio window. While not the prettiest system, hopefully it gets the point across.

In conclusion, we can build it if the opportunity arises.

Fox-1E (RadFxSat-2) Telemetry

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Abstract

AMSAT satellites Fox-1A through Fox-1D (the FM "Fox" series of CubeSats) all send or will send telemetry at about 200 bits-per-second using a technique called Data Under Voice (DUV). DUV uses Frequency Shift Keying (FSK) to carry data in the baseband spectrum below about 300 Hz. Fox-1E (officially known as RadFxSat-2), while using many of the same hardware components, contains a linear transponder with 1200 bits-per-second telemetry sent as Binary Phase Shift Keying (BPSK) on one side of the passband. This paper describes the Fox-1E telemetry including a new feature called Whole Orbit Data. It does not describe the modulation technique itself.

How We Can Use Six Times the Data Rate

As the hardware design for the Fox-1E solidified, we realized that we would be able to send data to the ground at about six times the rate that was available with the FM Foxes. However, the design also envisioned relatively small hardware changes compared to the FM Foxes. Thus, telemetry data continues to be produced at about the same rate. We had to consider how to make the best use of the additional downlink data rate given the limitations on telemetry data generation.

Mike McCann, KB2GHZ, proposed that Fox-1E should have the ability to provide "Whole Orbit Data" (WOD)[1]. In other words, we would collect satellite health data as well as science experiment data continually, save it in on-board memory, and downlink it in addition to the real-time and min/max data the FM Foxes send.

We decided to use the extra data rate for three things:

1. Use the majority of the additional rate to send previously-saved WOD
2. Collect a few more data items included in the telemetry, and
3. Put more data in a single frame, reducing the overhead.

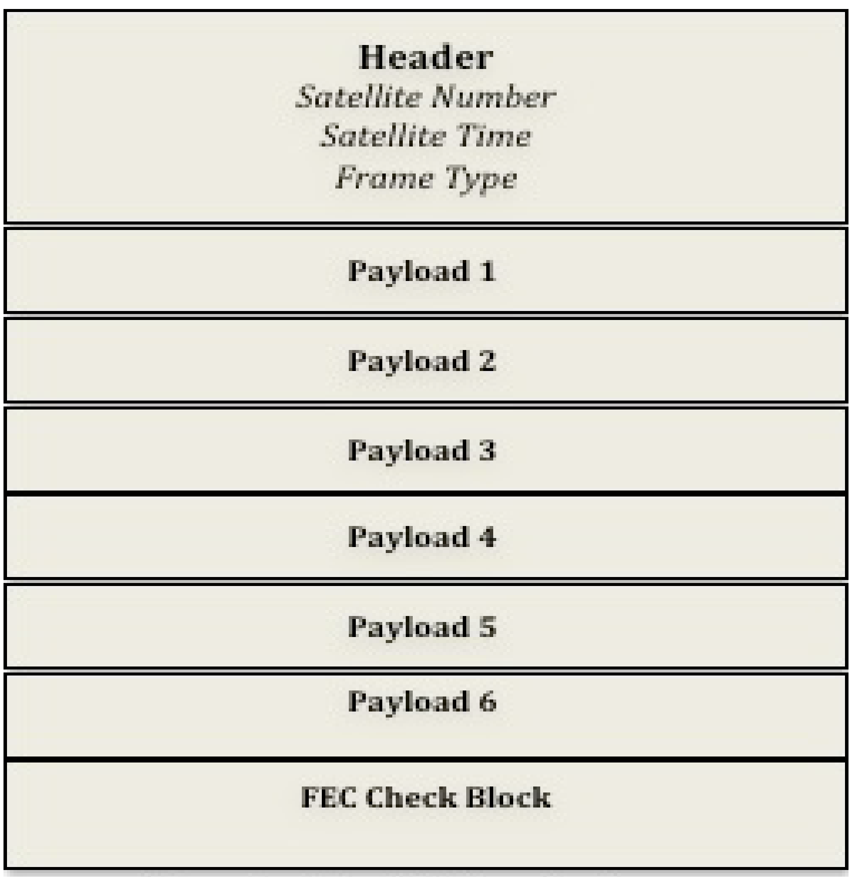

Figure 1 – A Fox-1E telemetry frame.

Fox-1E Downlink Protocol

The 2017 AMSAT Symposium Proceedings contain a large amount of information about Fox-1E that is not in the form of a traditional paper. Instead, copies of specifications and schematics published as AMSAT Fox-1A Systems Engineering Documentation serve to release that information into the public domain. One of those documents, "Fox-1E Downlink Specifications," by Burns Fisher, WB1FJ (ex W2BFJ) and Chris Thompson, G0KLA, is a spreadsheet with the detailed contents of each downlink frame and payload.

Also, earlier documents that describe the FM Fox telemetry scheme are still partly relevant. In particular, a paper by Phil Karn, et al., describes the forward error correction and the 8b10b line encoding, which all the Fox satellites use.[2]

Packets and Payloads

Fox satellites send telemetry in units called "frames" or "packets." Each frame starts with a header followed by a set of data, followed by check blocks used by the Reed-Solomon Forward Error Correction (FEC). The header specifies the spacecraft time, spacecraft ID, and the type of data within the frame. We call the actual data within frames "payloads."

FM Fox low-speed telemetry frames send four different types of payloads, and each frame contains one payload. Each FM Fox payload is 58 bytes, and the frame includes as overhead the header, as well as 8b10b line encoding and the FEC check block.

Because of the extra speed in Fox-1E, we can make the payloads a bit longer (78 bytes), and send six payloads for each frame. A longer frame also requires more bytes of check block .

Fox-1E also adds two different payload types, increasing the number to 6 (unrelated to the 6x data rate, or to 6 payloads per frame).

The payload types are as follows:

1. Real-time Health Data
2. Minimum Values Health Data
3. Maximum Values Health Data

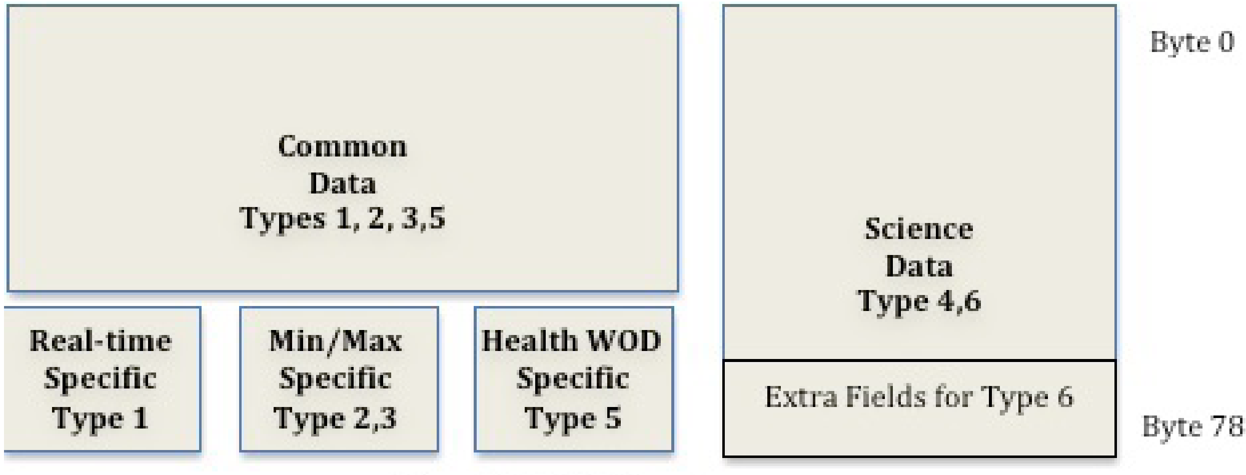

Figure 2 – Payload formats.

4. Real-time Science Data
5. Whole Orbit Health Data (Fox-1E only)
6. Whole Orbit Science Data (Fox-1E only)

The Fox-1E Downlink Spec, referenced above, defines the contents of each of these payload types.

Figure 1 shows a frame, which consists of a header, a sequence of six payloads and an FEC Check Block. There are 5 possible sequences of payloads, called Frame Types, numbered 0 through 4. Those types and their payload contents are:

0. All-WOD: Payloads 6, 5, 6, 5, 6, 5
1. Real-time: Payloads 6, 5, 6, 5, 1, 4
2. Min-Max: Payloads 6, 5, 6, 5, 2, 3
3. Real-time Beacon: Payloads 1, 5, 5, 5, 5, 5
4. WOD Beacon: Payloads 5, 5, 5, 5, 5, 5

During normal operation, frame types 0, 1, and 2 are sent. In some special modes like Science or Safe Mode, types 3 and 4 are also sent. Notice that EVERY frame type contains at least 4 WOD payloads and All-WOD, type 0, contains 6. All-WOD frames are sent most frequently in normal operation. For each minute of telemetry, we send about 12 frames consisting of 7 All-WOD frames and 5 Real-time or Min-Max. Normally then, we send 62 WOD payloads per minute: 31 Health WOD and 31 Science WOD.

Format of Payloads

The Fox-1E Downlink Spec referenced earlier is a spreadsheet that describes the frame header, a data structure called "common" and a separate data structure specific to each type of payload as shown in Figure 2. We use a Python program to read the spreadsheet and output C-language header files for the spacecraft flight software. There is a similar program to build spacecraft description files for the Fox ground software,

FoxTelem

Each health payload (real-time, min, max, and WOD) consists of the common data followed by the payload-type-specific data. Common data is the same in every health payload. Payload-specific data includes some status information that does not have to be sent with every health payload, and for min, max, and WOD includes a time stamp indicating either when the most recent min or max change occurred or when the WOD payload was originally collected.

Note that the science data does not use "common." It consists completely of data specific to the science experiment.

How WOD Works

MRAM

All the Fox-1 spacecraft contain a component called MRAM (Magnetoresistive Random Access Memory), a type of non-volatile memory with especially good characteristics for our purposes. MRAM parts essentially have no limit on the number of write cycles possible, and they have good resistance to radiation. In all the Fox-1 spacecraft, MRAM is used to store the minimum and maximum health values that the software has seen. Additionally, MRAM in the FM Foxes contains the digitized announcements by "The Voice Of Fox," Veronica Monteiro. Fox-1E has no recorded voice announcements, so we used the available MRAM space to store WOD.

Circular Buffer

The MRAM space vacated by the FM Fox voice announcements is arranged as a circular or ring buffer. Wikipedia displays a useful animated picture of a circular buffer, which appears (not animated) as Figure 3.

Note that this buffer has two pointers: a read pointer and a write pointer. Not surprisingly, the software uses the write pointer to enter data and then moves the write pointer forward. Similarly, it reads data at the read pointer location and moves the read pointer forward. Wikipedia describes the most common implementation: if the write pointer laps the read pointer, the buffer is full, and the software stops writing and loses data (this is what has happened when Windows beeps at you as you try to type to an unresponsive program).

Similarly, if the read pointer reaches the write pointer, there is no more data available, and the program stops reading. For WOD, we do it slightly differently. We transmit WOD data faster than we write it, and we wish to send many copies of the same data. Thus, the read and write pointers are completely independent so that when the fast-moving read pointer encounters the write pointer, it just continues. The software is careful not to read and write at the same time.

Another way to look at it is that the write pointer is the boundary between the oldest saved data and the newest. Every time there is a new set of data to write, it is written over the oldest data in the ring. Every time the read pointer crosses the write pointer, it starts over again with older data.

Figure 3 – Circular buffer.

Getting All the Data to the Ground

Suppose that the MRAM has room for 124 WOD payloads, WOD data is collected once per minute, and 31 WOD payloads are transmitted per minute. That means that each WOD data has a lifetime in MRAM of 124 minutes before it is overwritten. Since we transmit 31 payloads per minute, we have transmitted the entire buffer in 4 minutes. Thus each payload is transmitted about 124/4 or 31 times. You can see that if the memory changes size, we still send each payload 31 times, but the payloads will be less or more spread out in time.

As I said earlier, WOD data contains the spacecraft time at which the data was collected. This time uniquely identifies a WOD payload. The Fox-1 ground software is designed to ignore duplicate payloads no matter how many times they are received.

Despite the satellite not knowing whether what it sends is actually received, we have chosen a ring buffer size so that at least one ground station is likely to receive at least one copy of each WOD record that the spacecraft has collected. We determined this ring buffer size value by simulating WOD telemetry being received by ground stations that currently contribute AO-85 data regularly.[3] After launch, we can optimize the ring buffer size by changing it with a ground command.

Summary

This paper is one of a set of documents, all appearing in various AMSAT Symposium Proceedings, that describes the format and some of the rationale behind the telemetry on Fox-1E, also known as RadFxSat-2. While the data payloads transmitted by Fox-1E are specific to that satellite, the BPSK modulation technique is standard. This paper and the others referenced here should provide enough information so that an ambitious satellite listener could write his or her own decoder. Of course, an even easier way to decode the Fox-1E telemetry is to use AMSAT's FoxTelem program. A version of FoxTelem supporting Fox-1E is currently under test and will be available before the satellite is launched.

References

[1] "Fox-1E - Proposed IHU Firmware Features," Mike McCann, KB2GHZ, *AMSAT Symposium Proceedings, 2015.*

[2] "Coding and Modulation Design for AMSAT Fox-1," Phil Karn KA9Q, Paul Williamson KB5MU, and Michelle Thompson W5NYV; *AMSAT Symposium Proceedings, 2013.*

[3] **en.wikipedia.org/wiki/Circular_buffer**

Frequency Calibration for SDRs - Without GPS

Ray Roberge, WA1CYB

Summary

I will describe a program that calibrates your software defined radio (SDR) to frequency precise TV signals. By looking at your local TV signals, calibration to less than 100 Hz at 600 MHz is easily attainable even with an inexpensive RTL-SDR Dongle.

Perceived AMSAT Need

Making a satellite/terrestrial ground station as inexpensive as possible likely necessitates using some parts that have significant frequency error in the 5 GHz and 10 GHz bands. This would include the transmitter frequency determining components, baseband frequency source and all the mixers used to up-convert the baseband to 5->6 GHz (C-band). Similarly, on the receive side, we need to down-convert the signal to baseband with the possibility of intermediate conversions in between. In the end, to handle the modulation, a SDR probably will be needed to demodulate the received satellite data/audio/beacon, etc.

Solutions

The easiest and most expensive way to handle the frequency uncertainty is to use an atomic frequency source. The second best method is a GPS disciplined oscillator. With a moderate cost, this might be a preferred solution for many hams. The third method is to use a crystal oscillator and a way to calibrate its frequency. Finding an inexpensive calibration source will help make this method the least expensive. I created a free program to minimize the frequency uncertainty with such a source. This tool can easily be modified under GNU Radio Companion for other SDRs or used as is.

Different Methods

On HF, you could use WWV, WWVH, CHU or the Russian frequency and time broadcasts. If your source is low frequency, you could compare it to those broadcast frequencies and get some measure of accuracy.

However, achieving accuracy using these sources can be difficult because we need a way to calibrate a signal at significantly higher frequencies than the HF broadcast sources. You could use the harmonics of your oscillator by making a comb generator. If your crystal oscillator is portable with a fairly stable frequency, perhaps a local club could provide someone with access to a stable source for comparison.

Another method is to use a UHF broadcast. In the U.S., that would be the ATSC, high definition TV, signals. These signals use multiple frequency tones to broadcast the picture and audio via digital encoding. For their scheme to work, they need a reference frequency for the TV's AFC to lock onto. To prevent adjacent channel interference, that reference frequency — the "pilot tone" frequency — has to be common with its neighbor. The pilot tone frequency is what we exploit.

The mandated FCC frequency specification for TV stations is no longer required, but most stations have designs that predate that. Many have atomic clocks (Cesium or Rubidium). Alternatively, they may use a GPS disciplined oscillator. Now what remains is to find the pilot tones and see where your receiver says they are.

You can compare the two to determine the frequency error. By looking at several stations, you can determine your frequency error versus frequency. Once you know that, you can correct the slope of that error with your SDR ppm setting. There will then be some residual error because the radio's capability to set the ppm accurately is limited. We can measure the delta.

Why UHF Calibration is Good Enough

A block low noise downconverter like an Avenger, with its output at UHF, is a good fit for this calibration technique. If you have a direct down-conversion receiver, from 10 GHz to baseband, this program won't help very much. If your SDR has a wide band operating capability using the latest 70 MHz to 6 GHz chipsets, then you can also utilize this to calibrate your receiver.

Pilot Tone – Technical

For those interested in the technical aspects of the pilot tone, here are a few quotes and references:

1. "Consequently, the pilot frequencies of all transmitters in a network shall be maintained within ±1/2 Hz of nominal frequency (i.e., ±1 Hz of one another)." *"ATSC Standard for Transmitter Synchronization, Doc. A/110:2011, 8 April 2011 page 74.

$$\text{pilot frequency} = \left[6 - \frac{Tr \times \frac{208}{188} \times \frac{313}{312}}{4} \right] \div 2\ \text{MHz} = 309440.55944056\ \text{Hz (I used 309441 Hz)}$$

2. The formula for determining the location of the pilot with respect to the lower edge of the theoretical occupied bandwidth appears above.

Tr is the Transport bit rate, Tr (approximately 19.39 Mbps) in a 6 MHz channel From; ATSC Digital Television Standard – Part 2: RF/Transmission System Characteristics, Doc. A/53 Part 2: 2011, 15 December 2011

$$T_r = 2 \times \left(\frac{188}{208}\right)\left(\frac{312}{313}\right)\left(\frac{684}{286}\right) \times 4.5 =$$

19.3926584597511 Mbps

From: ATSC: "Digital Television Standard, Part 3 – Service Multiplex and Transport Subsystem Characteristics," Doc. A/53, Part 3:2009, Advanced Television Systems Committee, Washington, D.C., 7 August 2009.

This means that every 6 MHz, starting at 470,309440.55944056 Hz to 686.309 MHz you might have a constant CW tone to lock onto and calibrate your system if you have TV reception in your area.

The Program

The purpose of the program is to provide a spectrum plot and a waterfall plot of the ATSC pilot carriers. GNU Radio provides an easy way to implement a calibration program. Figure 1 shows the block diagram of the receiver. The SDR receiver that I targeted was a simple, inexpensive RTL-SDR dongle. Its frequency error was initially high but can be corrected to be less than 100 Hz at 600 MHz. GNU Radio is best run under the Linux operating system but can also run under Windows. You can find the program at **github.com/WA1CYB/satellite_ground_emulator/tree/master/Ascent/Frequency%20Calibration.**

Figure 2 shows a screenshot of the program using a RTL-SDR taken from my QTH in the Boston area. Ideally, the waterfall would have one straight red line as the receiver jumps between the six selected frequencies, all centered on zero Hz in the display. Use the Auto Scale button and the sliders to optimize the display. You can also change

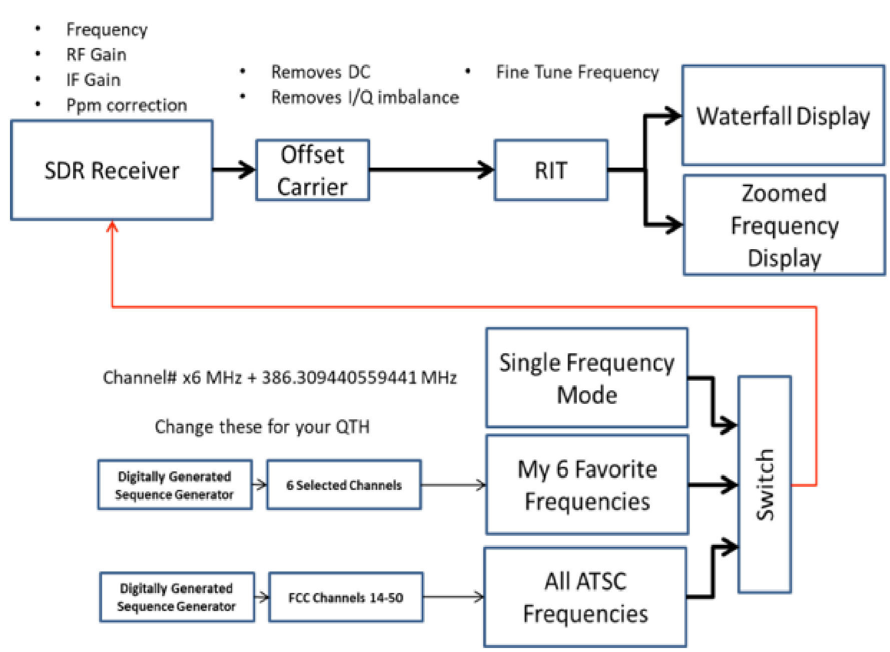

Figure 1 – Frequency Calibration Receiver Block Diagram.

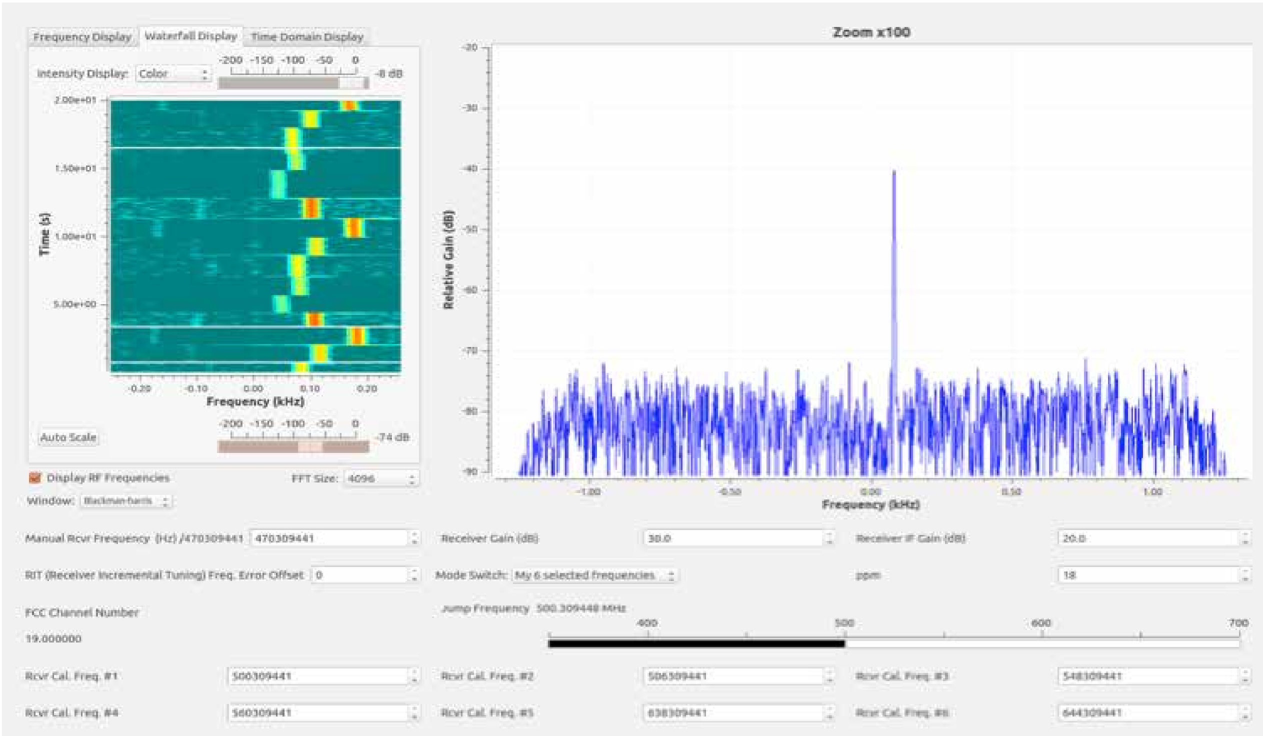

Figure 2 – RTL-SDR in six selected frequency mode, RIT = 0 Hz.

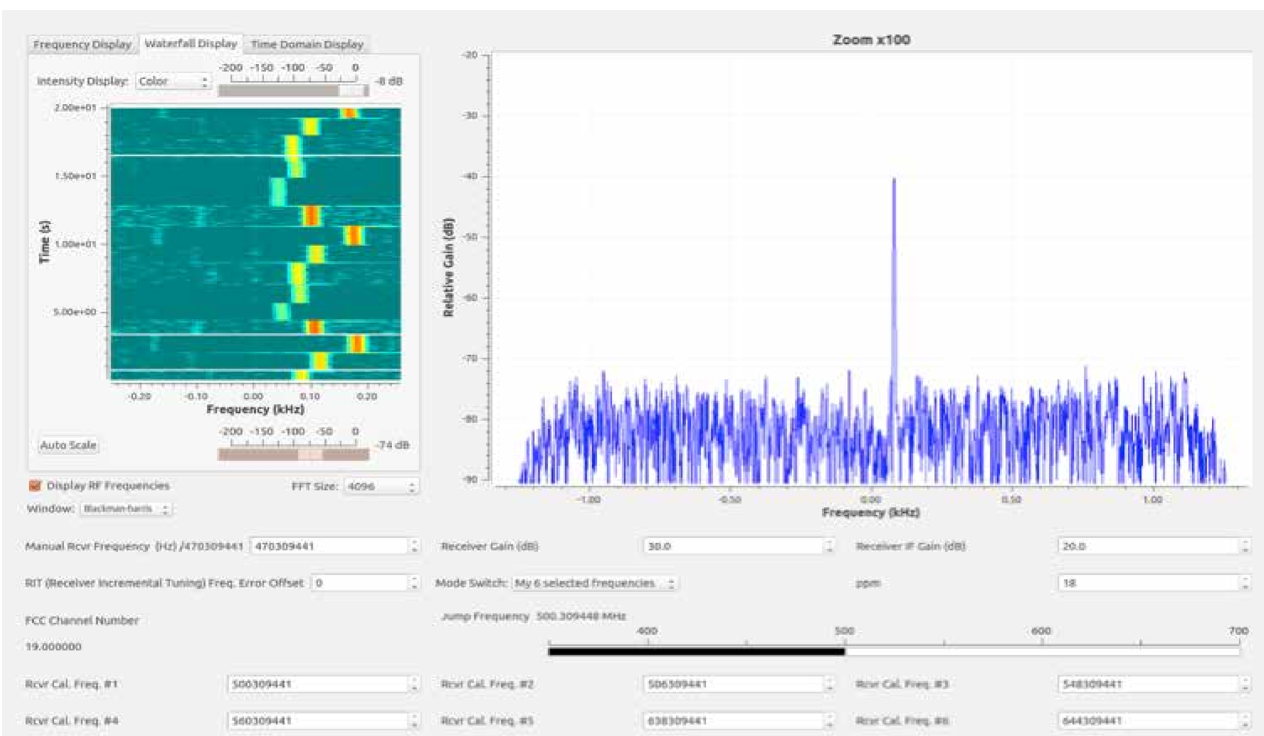

Figure 3 – ETTUS N-210 (un-calibrated) in 6 selected frequency mode.

the mode to scan all channels, or just look at one channel.

The part per million (ppm) setting is the major error source for this RTL-SDR. When you first run the program, use the frequency display tab on the left graph. This covers a wider bandwidth than the displayed frequency on the right. Change the ppm number to get the strongest channel as close as possible to zero Hz. After that, use the right-hand display along with the waterfall tab to fine-tune and center the group of selected frequencies as close as possible to zero Hertz. To finalize the calibration, use the receiver incremental tuning (RIT) to fine-tune the selected frequencies to the center of the waterfall. With the ppm and RIT values, you can optimize your frequency readout in your favorite program.

You can change the selected frequencies by using up/down arrows next to the selected frequency box. Note the arrows will increment the value by the channel separation, 6 MHz. Alternatively, you can type in a frequency or copy and paste the frequency in any of your six selected values. Figure 3 shows a screenshot of the program using an ETTUS N-210, with a GPS disciplined oscillator with no calibration routines done before the program was run. A much better starting point compared to the RTL-SDR, but at a cost. In my experience with other SDRs, performance is between these two SDR types.

The observant person will notice that the displayed jump frequency is not exactly the desired frequency (7 Hz off) even though the correct frequency (within 1 Hz) was sent to the SDR. The reason appears to be the limit of a 32-bit display/command. That's the best I could do with the standard GNU Radio flow graph. Another discovered oddity is that the ppm value can only be an integer. The reason is the RTL-SDR driver can take a ppm value with more precision, but the RTL-SDR ignores all but the integer portion. You can also observe the frequency drift of the SDR from a cold start. After 10 to 15 minutes the RTL-SDR is remarkably stable.

Conclusion

The ATSC TV signals in North America can be used to calibrate your SDR receiver with less than 100 Hz error up to the 23 cm band even with an inexpensive RTL-SDR. This tool provides a method to accomplish that. A calibrated SDR receiver makes operating your favorite satellite program easier to get on frequency.

Basics of How to Use SatPC32

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This article is intended as a "Getting Started" introduction to the SatPC32 program by DK1TB. Some capabilities are not covered here, such as rotor control. Please see Erich's online documentation (**www.dk1tb.de/indexeng.htm**) for more complete information.

Terminology Used: Menu Bar. The Menu Bar is the area just below the Title Bar at the top of the window where it says "File Tracking Satellites CAT," etc. (Figure 1a). Clicking on any of the items in the menu bar will either give you a pop-up window or a drop-down menu with additional items.

When I refer to a Menu item which displays a secondary menu, I list the Menu Bar item first, followed by two >> signs, followed by the item from the drop-down menu that should be selected. For example "Accy>>Countdown" means to click on "Accy" from the Menu Bar. Then, when the secondary menu appears, click on the item "Countdown."

When Buttons are referred to in the text, they are placed inside square brackets, as in [Registration] and [OK] in Figure 1b.

Figure 1b.

Section 1: Configuring SatPC32

A) On the first use of SatPC32: Enter your license information by clicking the [Register] button on the initial pop-up window.

From the Registration window, enter your call, name and the license code sent to you by AMSAT, then click [Store]. To continue in Demo mode, enter your longitude and latitude and click [OK].

B) Update Keplerian Data: Keplerian Elements, also called Two Line Elements or TLEs, are the information used by satellite tracking programs to define the orbits of the satellites. You must update these in your tracking program periodically, typically once a week or more frequently. To do this, click on "Satellites" in the Menu Bar, then from the Satellites window, click on the button labeled [Update Keps] located in the bottom right corner of the Satellites window (Figure 2).

A window similar to the one in Figure 3 will appear. Click on the first line in the window, then click the [Download] button. If successful, a small popup window stating "Download Successful" will appear. If you are in doubt as to which configuration file you will be using, you can't go wrong by updating each line in the list.

C) Create Satellite Group(s): Satellite groups are defined by clicking on "Satellite" in the menu bar at the top of the screen. Select the Kepler file you will use from the first column. When you double-click on a satellite name from the second column, it will appear in the third column. Click [OK] to save your changes. Before saving, you may want to click [Sort] and rearrange the order.

To change or create a new satellite group, click on the [Groups] button (Figure 2). I created a second group called CubeSat that includes the satellites listed.

D) Activate Countdown screen: This handy utility will show you the next time each of the satellites in your group will be in range. To activate, click on "Accy>>Countdown" in the Menu Bar. Check "Attach to Main Window," then check "Open Window at Program Start." Select the elevation of your horizon using the "Minimum Elevation" up/down arrows, then click the [Store] button. When a satellite is in range, the line for that satellite will be highlighted. In the example shown in Figure 4, both FO-29 and AO-73

Figure 1a.

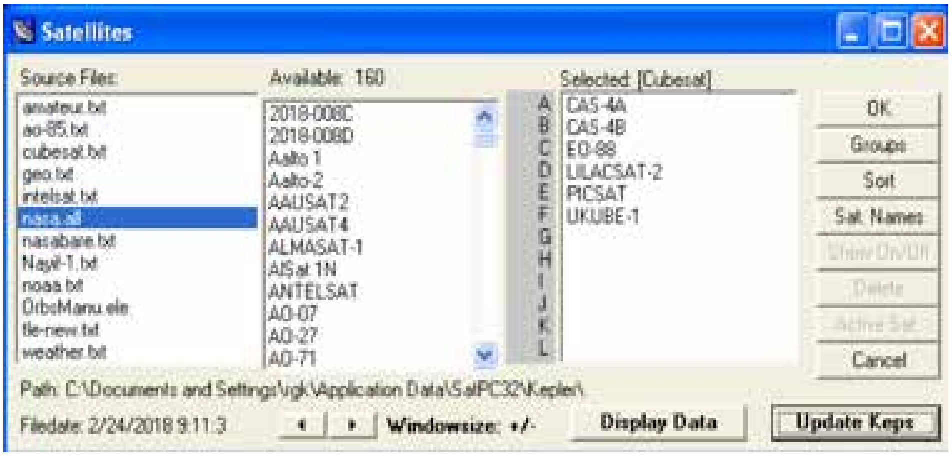


Figure 2.

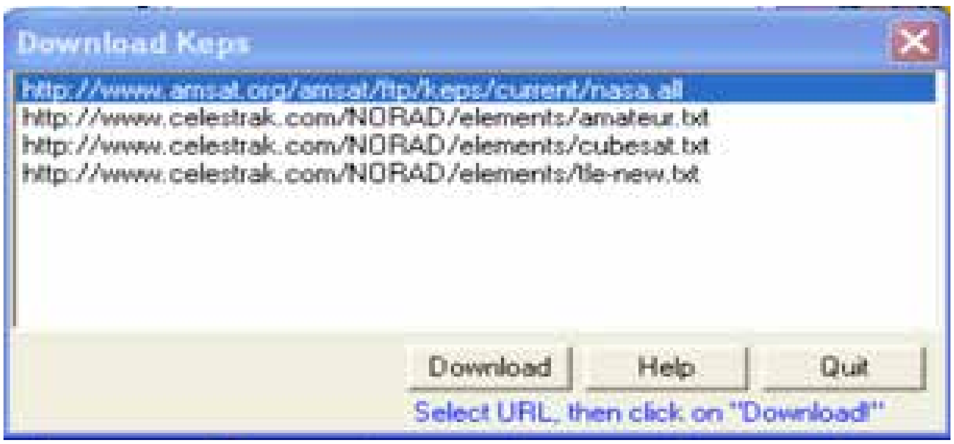


Figure 3.

are in range.

E) Set your location: From the menu bar, click on "Setup>>Observer." As shown in Figure 5, click on each item in the center column and set the value in the field on the right. After entering your Station Grid Locator, click the [Locator > Degs] button to insert the latitude and longitude of the center of the grid square into the next two lines. Leave "UTC offset" and "Source file mask" unchanged, then click the [Store] button.

F) Configure Radio CAT control: From Menu Bar, select "Setup>>Radio Setup." As illustrated in Figure 6a-b, configure Model and Baudrate as appropriate for the radios you use. Click the [Store] button. See the official documentation for additional information. Subdirectories exist for Icom, Kenwood, and Yaesu under the SatPC32 program file folder. Check the contents of those directories for additional information about those radios.(See the example of Yaesu Folders with additional information in Figure 7.)

G) Configure general Options: From Menu Bar, select "Setup>>Options." Figure 8 shows the options I use. After setting options, click the [Store] button.

Section 2: Basics of Using SatPC32

A) Selecting a Satellite: In the bottom right corner appear the letters A to L. SatPC32 allows you to have up to 12 satellites in one satellite group. Click on a letter from A to L and the assigned satellite will be displayed. If less than 12 satellites are defined in the current group, the unused letters will be grayed out. If a letter is highlighted, as is "E" in Figure 9, the corresponding satellite is in range.

B) Toggle Switches: In the top left of the main window are a series of toggles (Figure 10). The most commonly used are C-/C+ and T0/T1. See the official documentation for information and the rest of the toggles. C+ activates radio CAT control. C- displays if the CAT control is turned off. T0 / T1 / T2 are tied to subaudible tones. T0 means no tones are active, T1 means the first tone is active, and T2 means the second tone is active. Currently, only SO-50 has more than one tone.

Subaudible tones are defined in files accessed from the menu bar by clicking on

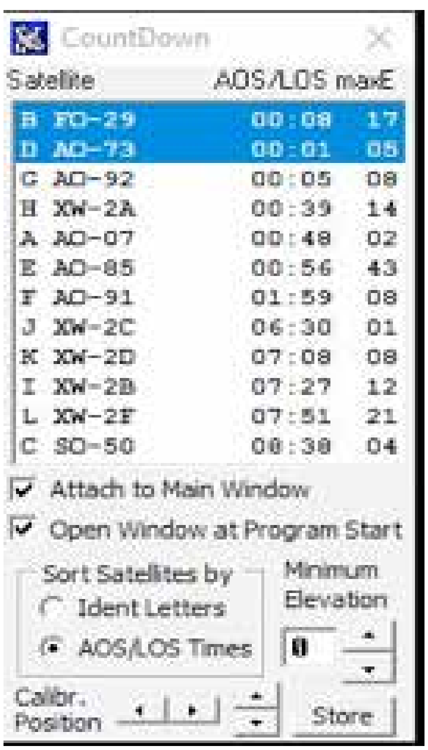


Figure 4.

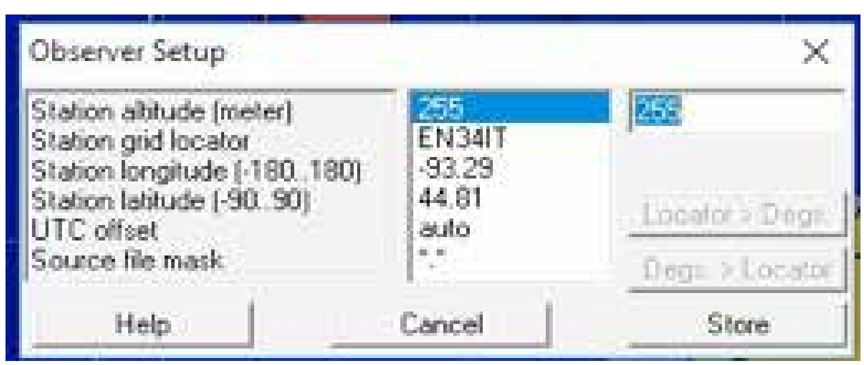


Figure 5.

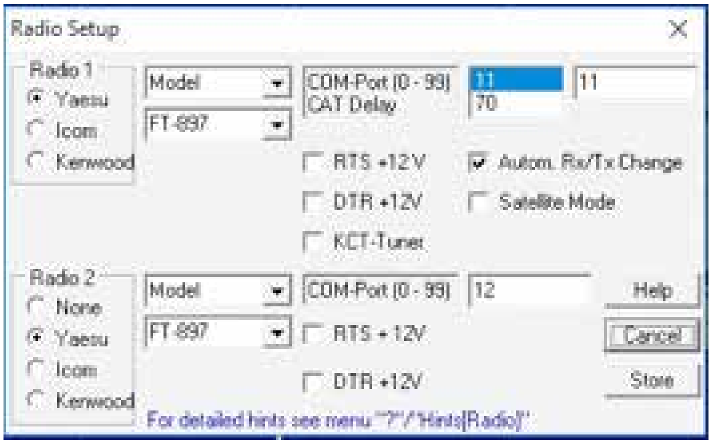


Figure 6a.

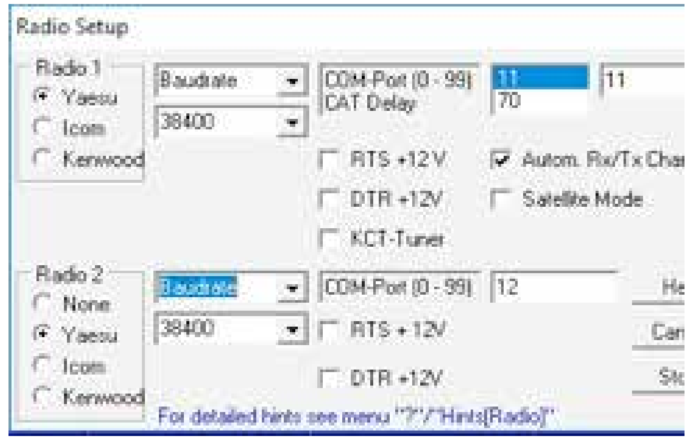


Figure 6b.

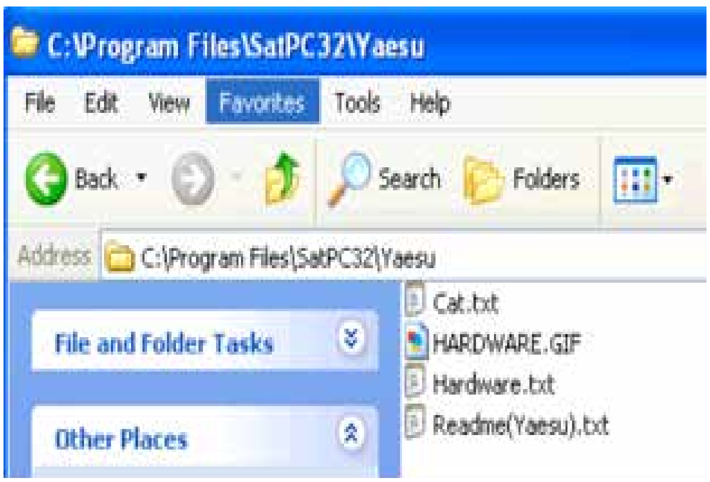


Figure 7.

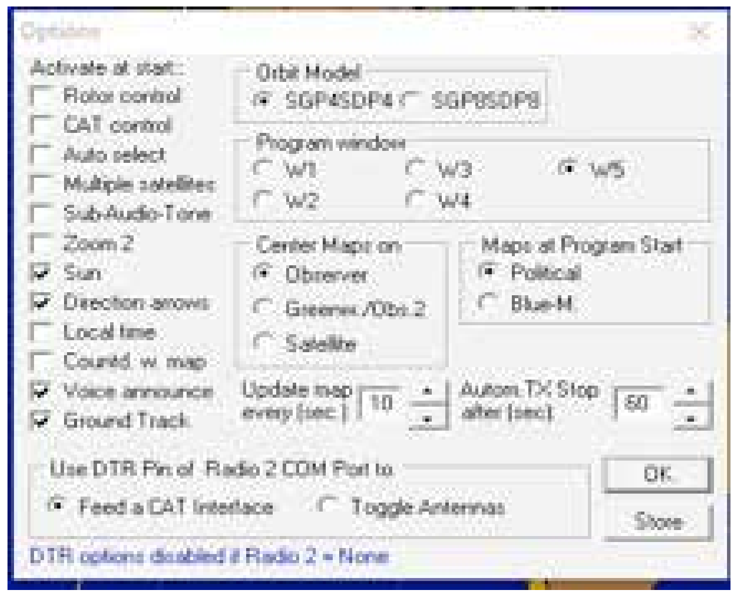


Figure 8.

Figure 9.

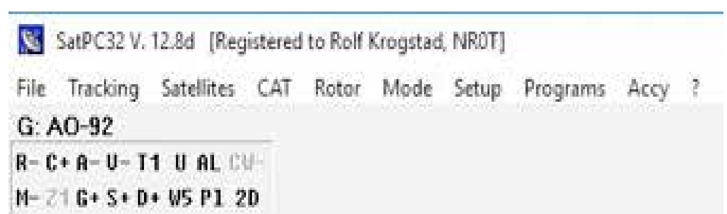


Figure 10.

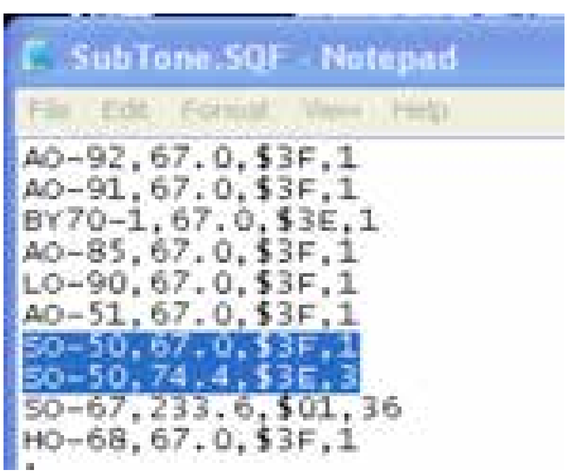


Figure 11.

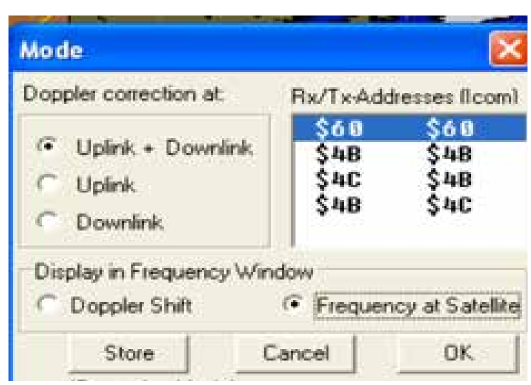


Figure 12.

?>>Auxiliary Files>>SubTone.SQF.

In the example shown in Figure 11, tone 67.0 is used for T1 on AO-92, AO-91, SO-50 (and other inactive satellites). Satellite SO-50 has a second tone, 74.4 Hz, defined as T2. That is used to turn on the transponder. SO-50 has a 10-minute timeout for the transponder. If you are the first person on SO-50, which can happen for people in Minnesota on passes which have AOS from the north, you may have to set T2, depress the mike button for two seconds, and then set the control to T1 before transmitting as normal. If you hear audio on the downlink, you won't need to send the 74.4 Hz subaudible tone.

C) Frequency Display: The frequency appears in the top center of the window (Figure 12). It shows the Downlink and Uplink frequencies for the selected satellite. There are two display options here. Click on "Mode" in the Menu Bar at the top of the window.

Current accepted practice when using CAT control of the radio(s) is to set the option "Doppler correction at:" to Uplink+Downlink.

"Display in Frequency Window" is a matter of preference. I like the option "Frequency at Satellite," as this is what is printed on the AMSAT Amateur Satellite Frequency Guide (Figure 13).

The other option, "Doppler Shift," reflects the offset amount caused by Doppler shift (Figure 14).

The up and down arrows can be used to change the frequency of the radio (Figure 14). I never use these. This capability was important on older radios where the CAT control was only in one direction, from PC to the radio. If the operator changed the frequency on the radio, it was not reflected in SatPC32. One example of such a radio was the Yaesu FT-736R. With more modern radios, using these controls is more cumbersome than simply using the VFO knob on the radio to change the frequency.

D) Time and Eclipse Indicator: Time will be displayed either in UTC ("U") or local ("L"), as depicted in Figures 15, 16. Changing between UTC and Local is set by the "Local Time" checkbox in "Settings>>Options."

Just above the time display is an indicator that reads either "Sat in Sun" or "Sat Eclipsed" (Figure 15, 16). For a few satellites, this indicator reflects whether a particular satellite's transponder is on or off depending on whether the satellite is in Eclipse or is in the Sun. For example, AO-7 only works when its solar panels are in the sun. Also, see notes for AO-73, EO-79, EO-88 on the AMSAT "Amateur Satellite Frequency Guide" for information on those satellites' restrictions.

E) Pass Information: Some key information about the next pass of the selected satellite appears on the bottom left. If the satellite is in range, Azimuth and Elevation will tell you where to point your antenna. Also, AOS will show ***** if the satellite is in range. If not in range, the AOS time will be listed. LOS signifies the end of the pass. MaxE is the maximum elevation over the duration of the selected pass. The example in Figure 17 shows a pass where the satellite is in range. Note AOS is *****.

This example in Figure 18 is a pass which is not in range. AOS is at 19:16 and LOS at 19:26 with a Maximum Elevation of 10 degrees above the horizon.

Note that the satellite selector "E" is highlighted. That means that the satellite defined as E in the current satellite group is currently in range. It does not mean that this is the satellite which has been selected. The selected satellite is found by looking at the top left of the window just above the toggles:, e.g.,"F: UKUBE-1" (Figure 19).

Figure 13.

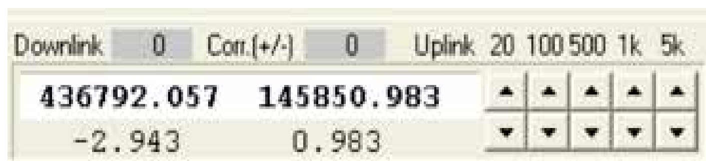


Figure 14.

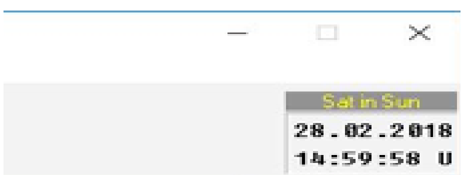


Figure 15.

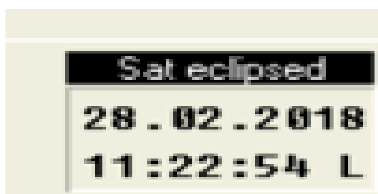


Figure 16.

Section 3: Miscellaneous Items

A) Adding New Satellites: Click on "?>>Auxiliary Files." Update two files: Doppler.SQL and AmsatNames.txt as described in the file comments. If the new satellite is an FM bird that uses subaudible tones, also update SubTones.SQF.

The names used must agree with the name in the Keplerian data file you are using.

Here is an example of the DOPPLER.SQF file entry for AO-92:
AO-92,145880,435350,FMN,FMN,NOR,0,0,U/V

Item 1 is the satellite name, item 2 is the downlink frequency, item 3 is the uplink frequency, item 4 is the downlink mode, item 5 is the uplink mode, item 6 is NOR or REV depending on whether the satellite

Figure 17.

Figure 18.

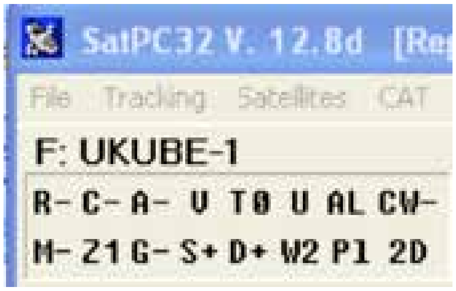


Figure 19.

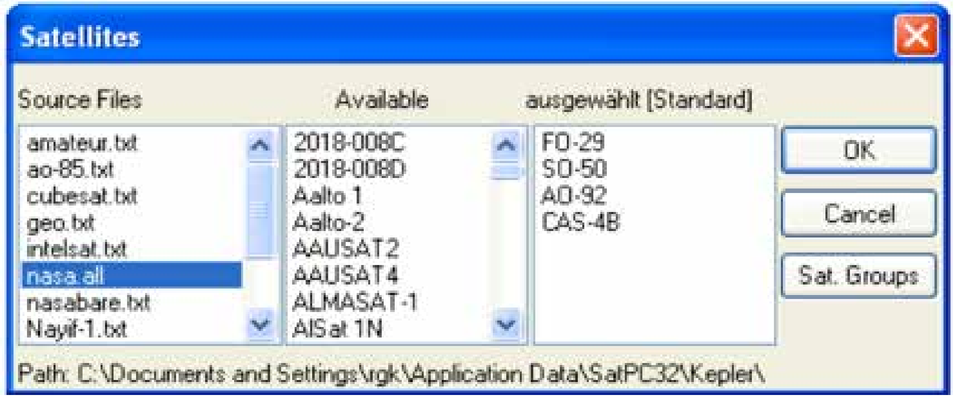


Figure 20.

is inverting or non-inverting.

Below is the entry for CAS-4B, an inverting linear satellite. For linear satellites, the frequency entered typically is set to the center of the passband:

CAS-4B,145925,435278.5,USB,LSB,REV,0,0

If the satellite is an FM satellite that requires the use of a subaudible tone on the transmitted signal for access, then you must define that in SUBTONES.SQF. Here is an example of configuring the 67 Hz tone for AO-92: AO-92,67.0,$3F,1

See the comment section in each file and also the official documentation for more details on each of the Auxiliary Files.

B) WinAOS: This will give you a schedule of satellite passes over a time/date range which you wish to see. It is available from the SatPC32 Programs Menu dropdown list, but it can be run as a standalone program, meaning that you don't have to run SatPC32 first. If you prefer, you can create a shortcut directly to WinAOS.exe on your desktop.

Select your Kepler file from column 1, select the Available satellites you want to include from the central column, and the third column will display the satellites you have selected (ausgewählt), as shown in Figure 20. The third column display will default to the Satellite Group named "Standard." You also may modify the list or select a different group. The order of the satellites is not important. When you are done selecting the satellites, click [OK].

The next screen that pops up is the time frame for the report. Select the date and starting time and then the duration of time that you want the report to cover. In Figure 21, I have selected March 17, 2018, starting at 15:30 UTC for a duration of 5 hours. Note that the date is in DD-MM-YYYY format. The timezone will depend on whether you select UTC or Local in the main program setup as described above. Click [OK] to generate the report.

Figure 22 depicts what the WinAOS report looks like. If you click on a satellite name from the Objects column, all entries for that satellite will be highlighted, as in the example shown, where AO-92 is highlighted.

AOS , LOS, the maximum elevation and the range of the Azimuth from AOS to LOS all are displayed.

C) Observer 2: Another handy function is Accy>Observer2. This feature will allow you to mark another location so you can see on the map when that grid is in range of the pass. In Figure 23, I have entered the grid BK29kr in Hawaii. The grid selection will create three Plus signs on the map: my location in Minnesota, the satellite's position and the location of Observer 2 (Figure 24). I then can see at a glance when both my location and the Observer 2 location are in the footprint of the satellite.

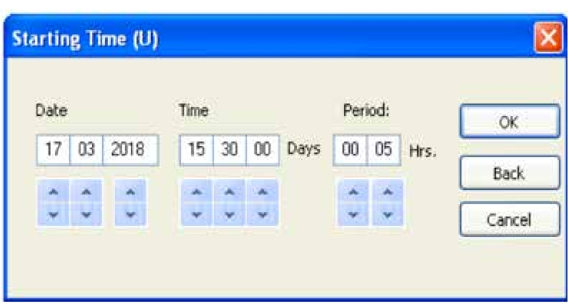
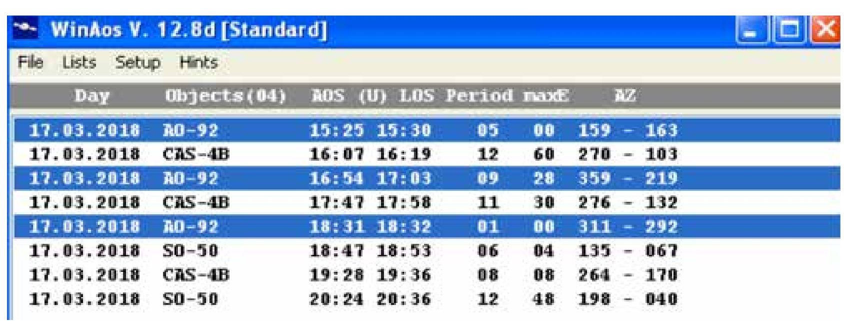


Figure 21.



Day	Objects(04)	AOS (U)	LOS	Period	maxE	AZ
17.03.2018	AO-92	15:25	15:30	05	00	159 - 163
17.03.2018	CAS-4B	16:07	16:19	12	60	270 - 103
17.03.2018	AO-92	16:54	17:03	09	28	359 - 219
17.03.2018	CAS-4B	17:47	17:58	11	30	276 - 132
17.03.2018	AO-92	18:31	18:32	01	00	311 - 292
17.03.2018	SO-50	18:47	18:53	06	04	135 - 067
17.03.2018	CAS-4B	19:28	19:36	08	08	264 - 170
17.03.2018	SO-50	20:24	20:36	12	48	198 - 040

Figure 22.

Figure 23.

I can also use WinAOS to find common passes with another location. I just run WinAOS twice, once using my grid square and then using a grid square of interest. Then I manually compare the two reports for passes in common. I recently used these techniques to arrange a schedule with WH6XM on FO-29 to get Hawaii, my 50th state for satellite WAS, in the log.

In Figure 24, the large plus sign off the coast of British Columbia represents the satellite, the medium-sized plus sign is Observer 2 (Hawaii), and my location (Observer) is the smallest plus sign (in Minnesota on the right of the footprint).

D) Backing up files: From the Menu Bar, select Programs>>Data Backup. "Save Data" will create a backup folder as indicated in Figure 25. Erich, DK1TB, the author of the SatPC32 software, recommends the following: When you have everything working the way you want it, that is a good time to do a backup of data.

The location of key configuration files, such as Doppler.SQF: C:\Users\UserName\AppData\Roaming\SatPC32. This location applies to Windows 10; WinXP will be slightly different.

At a minimum, the following files should be saved to an offsite backup. If you have to reinstall from the install media these files will be overwritten by older data:

Doppler.SQF: All satellite frequencies and any manual uplink frequency corrections you have made.
SubTones.SQF: All subaudible tones for FM satellites.
AmsatNames.txt: New satellite definitions tying Kepler names to AMSAT names are here.
UserDaten.txt.: This contains your license information. Do not share this information with others.

E) Time synchronization is critical. Check out Programs>>TimeSync or an external program like **www.meinbergglobal.com/english/sw/ntp.htm.**

I hope this summary will help you get acquainted with this fine software. SatPC32 is available for purchase from the AMSAT-NA web store.

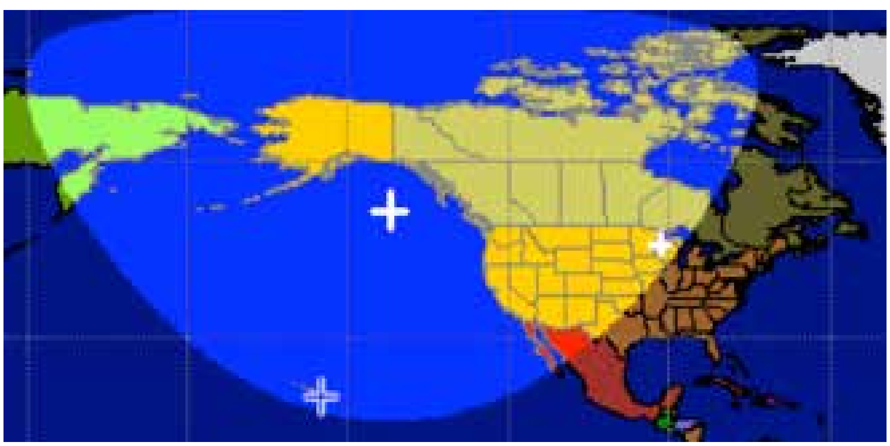


Figure 24.

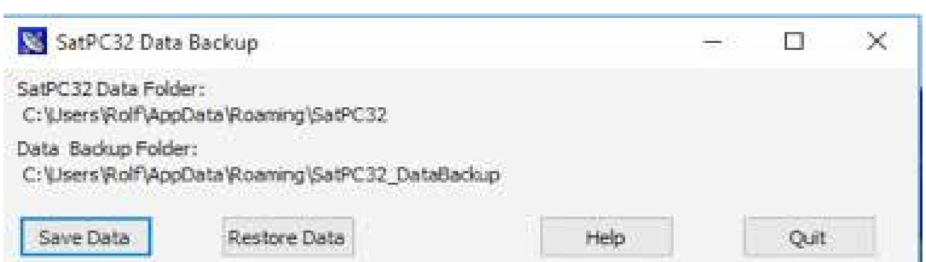


Figure 25.

An Update on Past and Future Projects from AMSAT-UK

David Bowman, G0MRF

Abstract

Since 2013, AMSAT-UK, together with AMSAT-NL and partners from industry and education have produced four CubeSats containing amateur radio transponders. This paper summarises the current status and lessons learned from the AO-73, UKube, EO79 and EO-88 missions. It also looks ahead to the launch of other satellites currently under construction, including the long-awaited L/V (1263 to 145 MHz) FM transponder on the European Space Agency ESEO satellite.

AO-73 / FUNcube I

1U CubeSat with UHF to VHF linear transponder. Telemetry at 1200 bps BPSK at 300 mW/35 mW 145.935MHz

- Launch: Dnepr from Yasny Russia. November 3, 2013
- Orbit: Sun-synchronous orbit at 630 km
- Collaboration: AMSAT-UK, AMSAT-NL, Innovative Solutions In Space (ISIS bv) Delft Netherlands.

Current Status

AO-73 has completed over 23,000 orbits and celebrated the 4th anniversary of its launch in November 2017. The 2 m transmitter runs high power telemetry when AO-73 is in sunlight, automatically switching to the transponder, and low power telemetry when the satellite is in eclipse. On weekends the satellite's transponder is active continuously from Friday evening to Sunday evening UTC.

As of October 1, 2017, AO-73 had returned more than 5.4 million frames or 1320 MB of unique data via the data warehouse. This includes 80.2% of all whole orbit data and 8.9% of real-time data (transmitted only once every 5 seconds). During the weekends over Europe, AO-73 continues to attract many QSOs on its transponder.

One lesson learned for AO-73 is that care must be taken with oscillator design, particularly on a 1U CubeSat. The low mass of the 1U format produces large temperature swings, particularly in eclipse. Of the three identical transponders fitted to AO-73 (1U), UKube-1 (3U) and EO-79 (2U), only AO-73 exhibits noticeable drift on the

70 cm uplink receiver. The local oscillator is a design that consumes very little power, and AO-73 runs several degrees colder than anticipated during pre-launch analysis. Neither characteristic aids oscillator stability. The satellite's systems have been very reliable with just four computer resets in 4 years. The power budget is excellent, and with only 5% to 6% depth of discharge in eclipse, the lithium-ion battery appears to be in good health despite 23,000 cycles of sunlight and eclipse. At the end of battery life, AO-73 has been designed to operate directly from its solar panels. Let's hope it's several more years before we discover if that design feature is successful or not.

UKube-1 (FUNcube 2)

3U CubeSat with UHF to VHF transponder + AMSAT telemetry at 1200 bps BPSK on 145.915 MHz.

- Launch: Soyuz from Baikonur in Kazakhstan. July 8, 2014
- Orbit: Sun Synchronous at 615 km
- Collaboration: UK Space Agency, Clyde Space, AMSAT-UK, AMSAT-NL and other payload suppliers.

UKube-1 was the first mission for the UK Space Agency. Led by the Scottish company Clyde Space, this 3U satellite functioned as a technology demonstrator for four major science payloads. These included a camera design from the Open University and an experimental random number generator driven by radiation. While data was downloaded from all of the core payloads, the satellite suffered multiple computer resets per orbit.

In October 2015, after one year of operation, the UK Space Agency declared "end of mission."

Current Status

Personnel operating the UKube command station were reassigned in late 2015. However, the satellite is still active with occasional signals from its primary communications system on 145.840, and with the AMSAT-UK supplied transponder and the telemetry sub-system operating 24/7. Although this satellite is not actively managed, it has a large number of solar cells fixed to the 3U structure and on its deployable panels. Consequently, the power budget is positive and the Clyde Space EPS and lithium polymer batteries have a good state of charge throughout the orbit. The frequency stability of the transponder is better than AO-73 as the mass of a 3U CubeSat reduces extreme swings of temperature.

However, the transponder does suffer from desense to its UHF receiver when beacon transmissions occur from the primary communications system. Use of telemetry, in particular whole orbit data from the satellite for educational outreach, has been compromised by the large number of computer resets in the main OBDH which affects data collection.

EO-79/QB50 P1 (FUNcube 3)

2U CubeSat with UHF to VHF linear transponder. Downlink 145.946-145.971 MHz. Uplink 435.0723 – 435.0473 MHz. No AMSAT telemetry, but the primary system beacons on 145.815 MHz.

Figure 2 - UKube. 3U CubeSat with deployable solar panels at ClydeSpace 2013.

- Launch: DNEPR from Russia.June 19, 2014
- Orbit: Sun-synchronous orbit at 600 km
- Collaboration: von Karman Institute for Fluid Dynamics, Innovative Solutions In Space (ISIS bv) Delft Netherlands, AMSAT-NL and AMSAT-UK

QB50 P1 and QB50 P2 were technology demonstrators or precursors for the QB-50 project. These 2U satellites tested the design of the science instruments for the QB50 mission. In acknowledgment of the use of amateur radio spectrum for the 50 CubeSat mission, the von Karman Institute agreed to include amateur radio transponders on the two precursor satellites. These were to be activated after the primary mission had been completed.

Current Status

The EO-79 transponder was made available for amateur use on a regular basis from November 12, 2016. However, the power consumed by the satellite with its attitude control system and other payloads have left the CubeSat with a potentially negative power budget. If the transponder is switched on, the battery is depleted within four or five orbits. To combat this power drain issue, engineers at ISIS developed and uploaded new flight code to the satellite. This code detects the transition from eclipse to sunlight and allows transponder activation based on programmable timers.

Transponder timing as implemented on EO-79:

- T=0 Satellite exits eclipse. Typically over the Southern Ocean. Delay timer starts/battery charges in sunlight.
- T=27 mins. Transponder activates. 25 min transponder timer starts. – Satellite is on ascending pass traveling S to N.
- T = 52 mins. Transponder switches off after 25 mins on time. Satellite is now typically at 55 degrees north.

The satellite then has a period of around 10 minutes in sunlight for it to add some charge to the battery. It passes into eclipse with the transponder off, but with enough charge in the battery to operate until the next period of illumination.

In late October 2017, the satellite's primary transmitter on 145.815 MHz and the AMSAT transponder fell silent due to an anomaly. Listening carefully it is possible to hear very weak telemetry, but I would estimate the radiated power to be no more than 1 mW.

The EO-79 command station recently commented:

"The AMSAT transponder on EO-79 is currently inactive since the spacecraft is being kept in safe mode after an anomaly has been detected on board. Investigation into this anomaly is taking longer than expected due to operator and station availability but is ongoing. The nature of the anomaly is such that it should not preclude resuming transponder operations after the investigation has been concluded, which will be announced through the usual channels."

EO-88/Nayif - I

1U CubeSat with 30 kHz wide inverting UHF to VHF linear transponder. Uplink 435.030 MHz. Downlink 145.975 MHz. BPSK telemetry @ 1200 bps BPSK on 145.939 MHz.

- Launch: PSLV-C37 from Sriharikota, India. February 15, 2017
- Orbit: Sun-Synchronous at 495 km
- Collaboration: Mohammed bin Rashid Space Centre (UAE) and American University of Sharjah, Innovative Solutions in Space (ISIS bv) Delft Netherlands, AMSAT-NL and AMSAT-UK

Current Status

Nayif-1 is owned and operated by the United Arab Emirates. This educational satellite carries an upgraded FUNcube transponder which includes a higher stability oscillator design. The satellite has active attitude control and features the usual "fitter" text messages but with optional Arabic language. Although manual commanding is possible, currently the satellite transponder is operating entirely automatically using eclipse or sunlight detection. The spacecraft operations can only be described as nominal.

Future Projects

JY1-SAT is a 1U Jordanian educational satellite project. The satellite, an initiative of The Crown Prince Foundation, is currently under construction in Amman Jordan and The Netherlands. The launch is planned for mid-2018 on a Space-X Falcon 9.

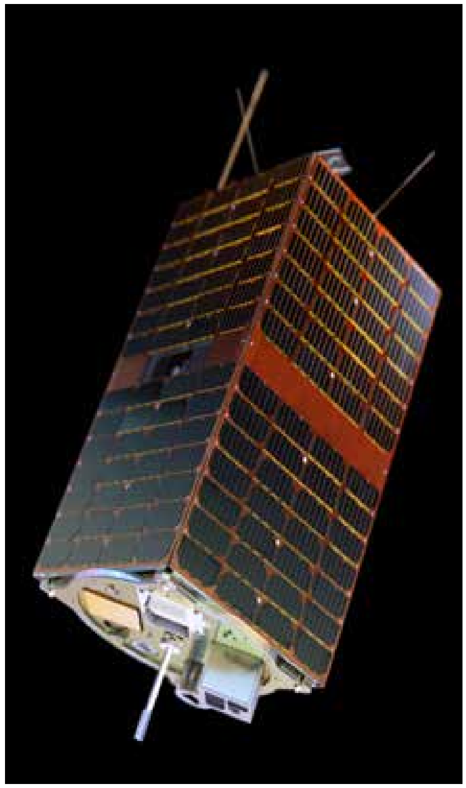


Figure 1 - ESEO. 50 kg 40 cm x 40 cm x 80 cm.

JY1-SAT is named after the late King Hussain of Jordan who held the callsign JY1. The satellite will carry another FUNcube UHF to VHF linear transponder with enhanced oscillator stability and have active attitude control.

JY1-SAT will transmit stored images reflecting Jordanian culture and historical heritage. The images will be transmitted in a digital SSDV format along with the standard FUNcube BPSK telemetry. Images will be decoded and displayed using the satellite's dashboard software.

ESEO - European Student Earth Orbiter

This 50 kg satellite is a hands-on project from The European Space Agency Education Office. The project has been running in several incarnations for about 10 years, but the spacecraft is now undergoing final integration. It is a collaboration between ESA and the prime contractor, Sitael, in Italy. Sitael is providing the structure and core satellite systems while universities from around Europe, together with AMSAT-UK, are providing a number of science and communication payloads. ESEO is three-axis stabilised incorporating attitude control using a combination of magnetorquers, momentum wheels and nitrogen gas thrusters. Communication between the satellite data handling system and the payloads uses a CAN bus based on the CANopen protocol.

Objectives of the AMSAT payload:

1) Educational outreach via telemetry on 145.895 MHz using 1200 bps BPSK in a similar way to AO-73

2) An FM transponder with L-band uplink on 1263.500 MHz and downlink on 145.895 MHz - CTCSS 67 Hz

3) Provide a backup communication system for transmitting science data at 4800 bps (primary system is 2.2 GHz)

4) To test new technologies, e.g., a real-time operating system using 32-bit processing and Silicon Labs factory programmed LVPECL oscillators for the L-band local oscillators and a CMOS VCXO for the FM

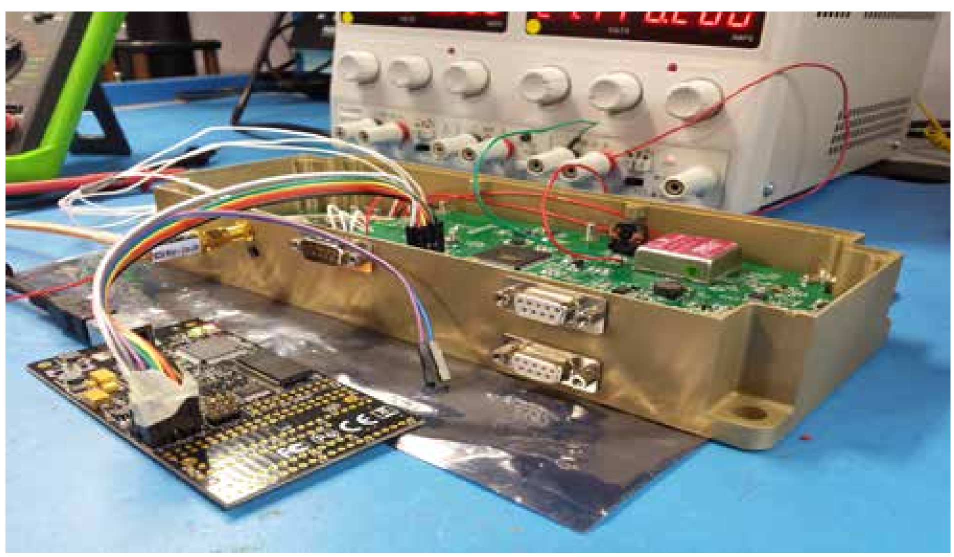


Figure 3 - AMSAT Payload (EM) being programmed at Surrey University.

Payload mode	Function	DC power use comparison
Receive only	Transmitters off but with telemetry data collected and stored to memory	22.0V at 114mA = 2.51W
Telemetry mode	BPSK TX on. Transponder off. With telemetry transmitted on 2m	Low power mode 4W High power mode 5.27W
Transponder mode	FM Transponder on. Uplink 1263.500 Downlink 145.895 MHz	Low power mode 4.2W High power mode 5.17W
Autonomous mode A	Transponder available while satellite is in eclipse. BPSK Telemetry on while in sunlight.	64 minutes at 4W or 5.27W 34 minutes at apx 3W Orbit average (hi pwr) 4.46W
Autonomous mode B	BPSK Telemetry transmitted until a 67Hz tone is received for 0.5sec on L band, then transponder is activated. System reverts to BPSK transmission 20 seconds after loss of CTCSS signal.	Very similar to telemetry only
Science mode	High power BPSK at 4800bps Sends real time tlm + data transfer from a selected science payload. Transponder is off.	5.27W

Figure 4 - RF output for BPSK telemetry in apx 100 mW/600 mW. RF output for the transponder is 400 mW/800 mW.

Figure 5 - ESEO. Command and transponder. L band receivers.

Figure 6 - Flight CCT Board with 32 bit Atmel processor.

transmitter. The telemetry and transponder downlinks share the same 2 m frequency. This design decision was made both to preserve available spectrum on the crowded 2 m band and to reduce the payloads power budget and provide some redundancy in the design by using separate BPSK and FM transmitters. The two transmitters are switched between a common low pass filter and 2 m quarter wave antenna using a GaAs switch from Skyworks.

ESEO will be launched into a LEO sun-synchronous orbit around 550 km with a high orbital inclination.

Transponder Receiver and Transmitter Characteristics

To access the ESEO transponder, a user will need to transmit a carrier that is on 1263.500 MHz at the satellite. A 67 Hz CTCSS tone usually will be required. Doppler shift on L-band is anticipated to be plus and minus 27 kHz at the horizon, so finding the correct frequency by hand is going take practice. The receive antenna on the satellite is a right-hand circular polarised patch which is printed on a PTFE substrate. With three-axis stabilisation, the patch usually will be nadir pointing but, as the antenna has gain, you may find that the satellite needs to be several degrees above the horizon before you are in the main lobe of the patch antenna.
The L-band receiver is a triple conversion superhet design with intermediate frequencies of 45 MHz, 10.7 MHz, and 455 kHz. Filter bandwidth of the 455 kHz stage in the transponder receiver is 15 kHz. Uplink audio deviation around 3 kHz should be sufficient, and testing has shown a signal of -112 dBm at the receiver will produce a satisfactory downlink.

The receiver's 67 Hz tone detector requires 500 ms of tone before the transmitter is activated. If the 67 Hz tone is lost, the transmitter will remain on for a period of 20 seconds. During this time, it will retransmit whatever signals are present at the receiver input.

The FM and the telemetry transmitters are both stable over a wide range of temperatures. Thermal vacuum testing covered multiple cycles between +70 degrees and -20 degrees centigrade. The transmitters can both be commanded into high or low power output, with transponder signals on 2 m being comparable to AO-85.

The 2 m transmit antenna is constructed around a Teflon-coated multistrand wire which is supported inside a 3 mm diameter carbon fibre tube. Due to restrictions around the launch adaptor, the 2 m antenna is mounted onto the space-pointing end of the satellite.

Telemetry Transmission

The normal telemetry mode will be 1200 bps BPSK with forward error correction. The format is similar to AO-73 with 4.3 seconds of data followed by the 700 ms characteristic "beep." Each frame contains 2048 bits of data. This includes an 8-bit satellite ID and an 8-bit frame type indicator. This is followed by 432 bits of real-time telemetry and then 1600 bits of either whole orbit data or a text fitter message. The 2048 bits are expanded to 5200 bits by applying FEC and, at a transmission rate of 1200 bps, take 4.3 seconds to transmit. With 700 ms of tones, the total frame time is 5 seconds.

However, unlike AO-73, only four text message slots of the 24 available have been included, allowing more time for sending telemetry. Data is gathered internally within the payload using I2C data transfer between the sensors and the processor. Telemetry collected from the main satellite systems, including the electrical power system and several 32-bit channels generated from magnetometer data is transferred via CAN.

Science Data Transfer

Commanding of the ESEO platform, e.g., scheduling and telemetry requests, are controlled via a communication system on 70 cm. Science payload data, however, is transferred to the ground by a dedicated student communications payload which operates in the commercial space allocation at 2.2 GHz. This system has data transfer rates from 100 kbps to 5 Mbs and uses a variety of modulation formats. If this system should fail, the science data can be transferred to the ground via the AMSAT payload at 4800 bps. When active, the 4800 rate still transmits AMSAT real-time data, but the science data replaces the final 1600 bits in each frame. Given the size of the data transfer required (including images) a hole map is used so that data that has not been received in one pass or orbit can be specifically requested for transmission.

Operational Modes

The AMSAT payload has six main operational modes. Each can be commanded directly from the ground on L-band or by the internal satellite scheduler. Additionally, some mode transitions will occur automatically, i.e., from high power to low power to receive only, if preset temperature limits are exceeded. The six modes are shown in Figure 4.

Tri-Border Activation

Pedro Souza, CU2ZG

Starting half a dozen years ago, I began a tradition of traveling for my birthday, which occurs in February. If I want to stay closer to home, my destination will be in the Northern Hemisphere where it is winter. Some years ago, I traveled south of the Equator to warmer lands. However, this year was no exception, and I decided to find a destination somewhere close. Among the options I considered, I chose Austria.

I began travel preparations two weeks before my trip. A week before my planned departure, Patrick, WD9EWK, mentioned on Twitter that if my travels would take me close to the tri-border point of Austria, Slovakia and Hungary, I would have a rare chance to activate three countries all at once. In fact, NZ5N had done that in summer 2011. I looked at the map and realized Vienna, my main stop, was a mere 60 km from that point. That was a trigger.

Preparations

I had to bring light equipment with me. When I travel to a place I've been before, I can take a full Arrow and a full-duplex FT-817/857 set that requires a separate travel bag, as I do on my usual Christmas trips to HM58. It's something else to visit a new country. You want SSB capability but light and compact.

I keep a Wouxun KG-UV9D in my car, with its standard long duckie and an AL-800 telescopic whip, along with the exterior Nagoya R3. Using AO-91's perfectly-timed SSO orbit that allowed for lunchtime QSOs, I ran a full set of tests with those antennas. The best turned out to be the AL-800 that started picking up signals at around 7 degrees, with AO-91 hearing me above 20. While good for casual daily contacts, that was not good enough for lower elevations. Being in the Azores, the middle of the Atlantic, the number of possible QSOs drops drastically when the footprint hits only half of the Continent. Most people will not select a pass that is "half empty." That creates a challenge in trying to work very low elevation passes where the odds of finding someone new are greater.

At home, two related factors provide me an advantage. First, the RF noise and interference in the islands are substantially lower than those found in highly populated areas like big cities. Second, I am surrounded by ocean. The ocean effect is noticeable in nearly every pass. So, the antenna plays a huge role. I simply take my Alaskan Arrow in its 3+8 configuration every morning to the car and bring it back home in the evening.

On the Continent, this is not practicable. I simply needed something smaller, lighter, and more compact that could be disassembled, provide enough directivity, and possess high front-back ratio to at least perform down to 1-degree elevation. I decided on the short Moxon (www.arsatc.org/projetos.html).

I built one and have kept it in the car. I can work AO-91 down to -1.5 degrees. The construction material used allows fast assembly and can pack in any travel suitcase occupying the same amount of space as the Alaskan Arrow in 2+5 configuration. You might be thinking "if it takes the same space why don't you just take the short Arrow with you on those trips?" Well, that requires two radios or a duplexer, right? I want light, really light, simple, but efficient. I tend to think about it as the Holy Grail for satellite antennas: light, small, simple, efficient, quick assembly, down-to-horizon, dual band, single feed, fits in a bag.

Thus, I had an antenna, the second Wouxun KG-UV9D Plus that is kept at home for full-duplex, and a FT-817. I had never used that 817 with the Moxon, but a test on AO-7 revealed that everything was in proper working condition.

Activation

From February 18 -21, I tried several times to work any satellite in the evenings from the hotel room in downtown Vienna. Assuming that the RF interference in the area would be high, my hopes were small. Surprisingly, I could work AO-92, CAS-4B, SO-50, and FO-29. However, the number of operators trying to work the satellite is higher than at home, which poses greater difficulty in logging any QSO. In those days, I did not get any.

A last-minute change of plans moved my Czech Republic visit to a day later than the date I had announced on Twitter and the AMSAT-BB. So, in morning of February 22, I found myself in OK land with an upcoming AO-92 pass. That pass logged me two QSOs. Happy and re-energized, my 50-minute drive to the tri-border point passed quickly but anxiously.

The plan was simple. I would work two good passes on AO-91, 11:10 and 12:46, plus AO-85 and AO-7. Not knowing the AO-7 status and the somewhat low angle of AO-85, I would skip those two satellites and maximize my opportunities on AO-91. I approached the spot from the Hungarian side. I knew the road would be snow-covered, but to my surprise, it was unsuitable for walking, too. Quickly looking at the map, I found two other options to get there: a second one from the Hungarian side, and one from Austria. The Austrian route was the most promising. I thought it was funny that to get on that road I had to leave Hungary, cross Slovakia and re-enter Austria. It is something you do not think about too often when you live far from a border, and it sounds like a long way.

Good thing that I still had about 45 minutes to spare, which allowed me to reroute just in time for the 200-meter hike to the spot carrying the Wouxun and the Moxon. The weather was good though. Despite the overcast skies, the temperature was holding at one degree Celsius.

The location, itself, is a sculpture park surrounded by farmland. Where the old border fences once existed now stood small pillars marking where the fences had run. A triangular landmark identifies where the three countries intersect. It holds an Ö on the Austrian side (Österreich), an S on the Slovakian side, and an M on the Hungarian (Magyarország) side. Indeed, it seemed a good spot for a summer picnic.

I took the few remaining minutes to check the equipment. I tuned into the Bratislava airport frequencies and immediately got signals.

I was able to hear the downlink right at AOS. What amazed me was the number of people trying to get in — way more than the previous days. The new "easy sats" are drawing the attention of many new operators from new DXCCs and grids, which is very positive. The downside is that they are not familiar with satellites but eager to log QSOs. Calling CQ or shouting their callsigns and grids every two seconds simply monopolizes the pass and has become common on every pass, especially on FM. I do not mind those who shout out, but not allowing for others to call back or, like me, trying to find the correct polarization reduces any chance for a QSO, for both them and me. Even so, I was able to log four QSOs.

Between passes, we just enjoyed our spot and had fun around the area. Activities from hugging the landmark so we could be in three countries at the same time, or throwing snowballs from one country to another, perhaps going over one to land on the third, made our day.

The second pass was overtaken initially by the Gibraltar station. Being a rare DX, everyone took the opportunity to call him and log a new one. I waited to let everyone log it; as soon as it sounded calm, I announced myself as "OE/OM/HA/CU2ZG JN88." I logged three QSOs on that pass.

Conclusions

I always learn new lessons within a few seconds after I experience them. I have taken gear with me to the U.S., Canada, Australia, New Zealand, U.K., Portugal mainland, Madeira and other islands within the Azores. So far, I have been active in eight grids and tried without success from three others. I have witnessed several other ways of operating satellites, but always assume that despite knowing the operating methods, different circumstances always arise. Sometimes it is someone's way of calling, or callsigns you are not used to, or even the number of people on the satellite. One useful tip is to take more than you need. Always. This might include extra batteries, cables, connectors, or simply extra radios. For this trip, I ended up not logging a single QSO on SSB, and the final option was to not use it at the tri-border point, although I had brought the radio with me.

Also, always test your gear before you leave home, and before every pass. One of the most frustrating things that has happened to me during a pass is not getting into the satellite, starting to wonder if there is a problem with the antenna, cable or radio, just to find out I have the incorrect configuration.

Plan for the unexpected. Anticipate delays or mishaps. If I would have had no spare time when I found the initially selected road would not take me anywhere, I would have missed one pass.

Too bad the JN87/88 line was standing just some 300 meters away to the south of my tri-point location; otherwise, it would have been a triple-country double-grid activation. Looking at the map as I write this article, I cannot deny I am a bit disappointed for not being in JN89 for that AO-92 pass from the Czech Republic. It was just a short drive to the north. Anyway, all fun.

Support AMSAT

AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. Version 12.8c is compatible with Windows 7, 8/8.1 & 10 and features enhanced support for tuning multiple radios.

Version 12.8c features:

- SatPC32, SatPC32ISS, Wisat32 and SuM now support rotor control of the M2 RC-2800 rotor system.
- The CAT control functions of SatPC32, SatPC32ISS and Wisat32 have been expanded. The programs now provide CAT control of the new Icom transceiver IC-9100.
- The accuracy of the rotor positions can now be adjusted for the particular rotor controller. SatPC32 therefore can output the rotor positions with 0, 1 or 2 decimals. Corrections of the antenna positions can automatically be saved. In previous versions that had to be done manually.
- The tool "DataBackup" has been added. The tool allows users to save the SatPC32 program data via mouse click and to restore them if necessary. •
- The rotor interfaces IF-100, FODTrack, RifPC and KCT require the kernel driver IOPort.SYS to be installed. Since it is a 32-bit driver it will not work on 64-bit Windows systems.
- SuM now outputs a DDE string with azimuth and elevation, that can be evaluated by client programs. Some demo files show how to program and configure the client.

Minimum Donation is $45 for AMSAT members, $50 for non-members, on CD-ROM.
A demo version may be downloaded from http://www.dk1tb.de/indexeng.htm

A registration password for the demo version may be obtained for a minimum donation of $40 for members and $45 for non-members. Order by calling 1-888-322-6728. The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.

AMSAT Fox-1Cliff & Fox-1D $125,000 Launch Initiative Goal

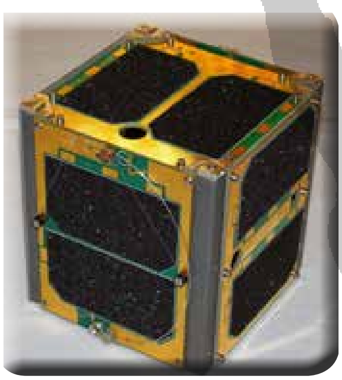
AMSAT is excited about the upcoming launch opportunities for the Fox-1Cliff and Fox-1D Cubesats. Fox-1Cliff and Fox-1D will provide selectable U/V or L/V repeater capabilities on separate frequencies once in orbit, and will be capable of downlinking Earth images from the Virginia Tech camera experiment.

AMSAT has an immediate need to raise funds to cover both the launch and related expenses for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses and help us to continue to keep amateur radio in space.

Fox-1Cliff will launch on Spaceflight's SSO-A dedicated rideshare mission aboard a SpaceX Falcon 9 scheduled to launch from Vandenberg Air Force Base in California in early 2018.

Fox-1D rode to orbit on an Indian PSLV vehicle launched from Satish Dhawan Space Centre in Sriharikota, India on January 12, 2018.

Donations may be made through the AMSAT webpage at **www.amsat.org**, by calling (888) 322-6728 or by mail to the AMSAT office at 10605 Concord Street, Kensington, MD 20895, USA. Please consider a recurring, club, or corporate donation to maximize our chance of success with this mission.



Your help is needed to get the AMSAT Fox-1Cliff and Fox-1D 1U Cubesats launched.

For the latest news on Fox-1 watch our website at www.amsat.org, follow us on Twitter at "AMSAT", or on Facebook as "The Radio Amateur Satellite Corporation" for continuing news and opportunities for support.

AMSAT President's Club
Support Fox-1Cliff and Fox-1D

Contribute to AMSAT directly through easy, automatic charges to your credit card. Since AMSAT is a 501(C)(3) organization donations may be USA tax deductible. (Check with your tax advisor.) To join contact Martha at the AMSAT Office by phone (888) 322-6728 in the US, or (301) 822-4376; e-mail **martha@amsat.org**.

Titanium Donors contribute at least US $400 per month	❐	$400 / month
	❐	$4800 one time
Platinum Donors contribute at least US $200 per month	❐	$200 / month
	❐	$2400 one time
Gold Donors contribute at least US $100 per month	❐	$100 / month
	❐	$1200 one time
Silver Donors contribute at least US $50 per month	❐	$50 / month
	❐	$600 one time
Bronze Donors contribute at least US $25 per month	❐	$25 / month
	❐	$300 one time
Core Donors contribute at least US $10 per month	❐	$10 / month
	❐	$120 one time

AMSAT is Amateur Radio in Space
... and YOU are AMSAT!

Seize opportunities to launch your amateur radio experience to new heights!

AMSAT Ambassadors - NEW

AMSAT Ambassadors program is looking for satellite operators to share enthusiasm for Amateur Radio in Space with others by:

- Promoting AMSAT at in-person events, practical demonstrations, online, or in written communications
- Offering personal mentoring and coaching to new enthusiasts either in-person or via online means
- Connecting members and potential enthusiasts with proper resources at AMSAT.

To volunteer, send an e-mail to Clayton Coleman, W5PFG at: **w5pfg@amsat.org**

AMSAT Internet Presence

AMSAT's information technology team has immediate needs for volunteers to help with development and on-going support of our internet presence:

- Satellite status updating and reporting.
- Add/delete satellites to ANS and the web as needed.
- Research and report satellite details including frequencies, beacons, operating modes.
- Manage AMSAT's Facebook and Twitter presence.

To volunteer, send an e-mail to Drew Glasbrenner, KO4MA at: **ko4ma@amsat.org**.

AMSAT Engineering Team

AMSAT Engineering is looking for hams with experience in the following areas:

- Attitude Determination and Control, and Thermal Engineering, to help in the design of high orbit CubeSats.
- Power systems, for CubeSats from 1U through 6U and LEO to HEO.
- Help with solar, power supply, and battery design for both LEO and HEO missions.
- Logistics, for parts procurement, inventory, and distribution.
- Documentation, for designs, tests, and public relations.

To volunteer, please describe your expertise using the form at **www.amsat.org/contact-amsat-engineering/.**

AMSAT User Services

AMSAT is looking for an on-line store co-manager to update and refresh the AMSAT Store web page when new merchandise becomes available or prices and shipping costs change.

- Add new merchandise offerings
- Delete merchandise no longer available
- Update shipping costs as needed
- Add periodic updates for event registrations
- Interface with the AMSAT Office.

To volunteer, send an e-mail to Joe Kornowski, KB6IGK at: **kb6igk@amsat.org**

AMSAT Educational Relations Team

AMSAT's Educational Relations Team needs volunteers with a background in education and classroom lesson development ...

- Engage the educational community through presentations of how we can assist teaching about space in the classroom.
- Create scientific and engineering experiments packaged for the classroom.
- Create methods to display and analyze experimental data received from Fox-1.

To volunteer send an e-mail describing your area of expertise to Joe Spier, K6WAO at: **k6wao@amsat.org**.

ARISS Development and Support

AMSAT's Human Space Flight Team is looking for volunteers to help with development and support of the ARISS program:

- Mentors for school contacts
- Support for the ARISS web
- Hardware development for spaceflight and ground stations
- Help with QSL and awards certificate mailing.

To volunteer send an e-mail describing your area of expertise to Frank Bauer at: **ka3hdo@amsat.org.**

Find more information at amsat.org. Click AMSAT – then click Volunteer.