Monthly Newsletter of International URSI Commission J – Radio Astronomy

January 2019

Officers

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News Items

Happy New Year Commission J Members!

This year marks the 100 year anniversary of of URSI! There are plans for the centenary book which URSI aims to publish in time for the URSI GASS in 2020. The goal of this book is to contain articles from each and every Member Committee and each and every Commission. Each article would include some historical context, something about contemporary activities, and something about the future. Commission J is actively looking for a lead author – if you are interested please contact me immediately.

The abstract deadline for the Pacific Radio Science Conference (AP-RASC) has passed. The Conference will be held in New Delhi, India from 09 – 15 March, 2019. A list of the Commission J sessions are given below. On behalf of URSI and the organizing committee, thank you for supporting AP-RASC 2019!

I continue to solicit workshop and session ideas for the 2020 URSI General Assembly and Scientific Symposium in Rome. A working draft of the 2020 GASS Commission J program is given below – we will continue to modify it over the coming months. Your input is needed – consider convening a session!

Our spotlight this month is on the phased-array feed (PAF) being developed for the Green Bank Telescope. I thank B. Shillue, K. Warnick, and D. J. Pisano for giving us a nice overview of the project, including its history, technical challenges, and future activities.

I kindly request your ideas, articles, news, photos, etc. for upcoming editions of Newsletter. Let's keep it interesting and informative! I thank all of you who have already contributed.

Submitted by R. Bradley

2019 URSI Pacific Radio Science Conference (2019 AP-RASC)

9 -15 March 2019, New Delhi, India

***** Abstract submission deadline has passed *****

See http://aprasc2019.com/ for details. The Commission J sessions are listed below.

J01: Evolution/Latest Results from uGMRT (Contributions and Felicitation of Govind Swarup)
Conveners: Subra Ananthakrishnan and Yashwant Gupta

J02: Updates from Existing Radio Astronomy Facilities – I
Conveners: Jayaram Chengalur and Douglas Bock

J03: Updates from Existing Radio Astronomy Facilities – II
Conveners: R Ramesh and Douglas Bock

J04: VLBI: Current Status and Future Prospects
Conveners: B C Joshi and Sergeyi Gulyaev

J05: Radio Astronomy Instrumentation & Techniques – I (Rcvr Systems: Analog/Digital/Optical Fibre)
Conveners: B Ramesh and S Srikant

J06: Radio Astronomy Instrumentation & Techniques - II (Data Processing: Imaging, Big Data)
Conveners: Dharam Vir Lal and Veeresh Singh

JGH7: Recent Scientific Results on Solar, Solar Wind and Space Weather Observations
Conveners: P Subramanian, Yihua Yan and P Janardhan

J08: Recent Scientific Results on Galactic, Extra-Galactic, Star Formation, Transients
Conveners: Ishwar Chandra and Kenta Fujisawa

J09: The Early Universe (EoR Experiments and Related Results)
Conveners: Abhirup Dutta and Tirthankar Roy Choudhury

J10: Future Radio Astronomy Facilities (including Square Kilometre Array)
Conveners: Divya Oberoi and Ramesh Bhat

EFGHJ-6: Upcoming Areas in Interference and Interference Mitigation
Conveners: Hanna Rothkaehl, Uttama Ghosh Dutta and Stefan Wijnholds

E07: RFI Mitigation in Radio Astronomy
Conveners: Subra Ananthakrishnan, Kaushal Buch and Tasso Tzioumis

EACFJ-8: EM Spectrum Allocation and Management
Conveners: Anjana Jain, Tasso Tzioumis and Jean-Benoit Agnani

JOS: Any Other Aspect of Radio Astronomy

2020 URSI General Assembly and Scientific Symposium (2020 URSI GASS)

Rome, Italy

We are now in the early stages of planning for the next URSI General Assembly and Scientific Symposium. Volunteer to convene a session or organize a one-day topical workshop around an important area of research. Let's work together to maintain the long tradition of excellence that the GASS provides to the radio science community.

***** Draft Program for Commission J – GASS 2020 *****

Sessions:

New Telescopes on the Frontier

Recent and Future Space Missions

Conveners: Joseph Lazio, Heino Falcke, Yuri Kovalev

Single Dish Instruments

Very Long Baseline Interferometry

Millimeter/Submillimeter Arrays

Receivers and Radiometers: Design and Calibration

Digital Signal Processing: Algorithms and Platforms

Short-Duration Transients and Pulsars: Observations, Techniques, and Instrumentation

Solar, Planetary, and Heliospheric Radio Emissions (Commissions HJ)

Ionospheric Models and their Validation (Commissions JG)

Characterization and Mitigation of Radio Frequency Interference (Commissions JEFGH)

Spectrum Management (Commissions ECJ)

Historical Radio Astronomy

Conveners: Richard Schilizzi

Latest News and Observatory Reports

Conveners: Rich Bradley and Douglas Bock

Workshops:

Space Weather (Commissions GHJ)

Meeting and Workshop Announcements

**** Registration open for a meeting on the History of the SKA: 1980s to 2012 ****

Dear colleagues,

We would like to draw your attention to a meeting on the History of the SKA from the 1980s to 2012, to be held from 3 to 5 April 2019 at the SKA Organisation Headquarters at Jodrell Bank. More information, including a registration form, is available at https://indico.skatelescope.org/event/518/

Richard Schilizzi, Ron Ekers, and Peter Hall
(Convenors)

1st International Cherenkov Telescope Array Symposium - Exploring the High-Energy Universe with CTA
May 6-9, 2019 - Bologna, Italy

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The first CTA Science Symposium will focus on the novel investigations CTA will bring to the field and its synergies with other wavebands and messengers. It will also cover instrument characteristics, analysis tools and opportunities for guest investigators and how coordinated observations with CTA will have a significant impact on the exciting new era of multi-wavelength and multi-messenger astrophysics. The symposium is a unique opportunity to gather the scientific community to stimulate discussion and promote collaboration in the study of the high-energy Universe.

CTA will be the largest and most advanced ground-based observatory for gamma-ray detection at the energies from 20 GeV up to 300 TeV, beyond the current energy frontier for gamma-ray astrophysics. With more than 100 telescopes located in the northern and southern hemispheres, CTA will use its unprecedented accuracy and sensitivity to reveal an entirely new and exciting view of the turbulent sky furthering our knowledge about the high-energy Universe. Learn more about CTA at http://www.cta-observatory.org .

- Join us!
Pre-register now to get further information about the meeting: http://www.cta-symposium.com
No payment is needed at this point. Feel free to forward this information to anyone who might be interested.

- Venue
The Symposium will be held at Bologna's magnificent Teatro Duse (http://www.teatrodusebologna.it/la-sala/), one of the oldest theatres in the city. Located in the historic centre and housed in the Palazzo del Giglio the theatre has been used since the mid-seventeenth century.

We look forward to seeing you in Bologna!

Stefan Funk and Jim Hinton for the SOC.

Activities Spotlight

Cryogenic PAF for the Green Bank Telescope

In March 2017, the FLAG phased array receiver (Focal, L-Band Array Receiver for the GBT) demonstrated the best sensitivity reported to date for a radio astronomy phased-array feed. The measured system temperature over efficiency was 25.4 +/- 2.5 K at 1350 MHz. The receiver consists of 19 dual-polarized dipole elements and formed seven simultaneous beams in each polarization, with T_{sys}/η comparable to the existing GBT L-band single pixel reciever. Commissioning results for this receiver have been published by D.A. Roshi, et al. in the Astronomical Journal [1].

History and Prior Work

PAF receivers have in the last 20 years gone from concept to prototype to fully deployed receivers on radio antennas. Rick Fisher and Rich Bradley of NRAO published an early work on phased array feeds for radio astronomy which was notable for establishing many of the primary considerations for PAFs on large reflector systems [2]. They laid out guidelines for the design and analysis of PAF receivers and began working on early room temperature demonstrators. During the following years, work continued at NRAO in this area, and a collaborative relationship was begun with the Brigham Young University (BYU) Radio Astronomy Systems group led by Brian Jeffs and Karl Warnick. The BYU group had been conducting R&D for radio astronomy leveraging PAFs for improved field-of-view, survey speed, and application to interference mitigation. BYU's work led to several publications presenting a new approach to modeling and beamforming and important early proof-of-concept demonstrations [3].

Two ambitious radio astronomy PAF projects were conceived and developed from 2006 to the present by SKA development groups at CSIRO (Australia) and ASTRON (Netherlands). These eventually were funded as the PAF Chequerboard array of the Australia SKA Pathfinder project (ASKAP) and the APERTIF PAF of the Westerbork Synthesis Radio Telescope. Both PAF receivers are used in a synthesis array, with a multi-element receiver on each dish, and the projects' status is that ASKAP is in use for scientific observations and APERTIF is in the process of commissioning [4,5].

North American PAF development work meanwhile focused mainly on single dish applications (at L-band), taking advantage of the large telescopes at Green Bank Observatory and the Arecibo Observatory [6,7]. These early U.S. efforts yielded a best result in terms of T_{sys}/η of 45.5 deg K.

A significant new effort to improve the performance of the single dish PAF receiver was initiated in 2013 as a collaboration between the "Beamformer" initiative, a joint development project of West Virginia University, BYU, and the Green Bank Observatory, and the NRAO Central Development Laboratory (CDL). The Beamformer group was funded by a National Science Foundation Advanced Technologies and Instrumentation Grant for *"Collaborative Research: Wide-Field L-band Focal Plane Array Beamformer for Pulsar, Diffuse Hydrogen, and Fast Transient Surveys on the GBT,"* with WVU as the scientific lead and

BYU over the correlator-beamformer digital back end. Green Bank Observatory had several roles, including project coordination led by Richard Prestage, project site host, and instrumentation support. The NRAO CDL team focused on receiver instrumentation development, electromagnetic modeling and beamforming. This collaboration produced and commissioned the FLAG PAF receiver and digital signal processing.

FLAG instrumentation development included several improvements over previous PAF prototypes:

1. Increased inter-element spacing and a larger cryogenic dewar to reduce mutual coupling and optimize the dish illumination
2. Second generation GBT (GBT2) dipoles optimized for efficiency over the receiver bandwidth
3. Custom designed, mechanically stable silicon-germanium cryogenic low noise amplifiers with low noise temperature (4.85 K median)
4. A custom, highly integrated 40-channel downconverter with 8-bit digitizers and digital photonic link packaged to fit directly behind the PAF cryostat
5. A 40-input-channel ROACH-2 based polyphase filterbank signal processor backend with 512 frequency bins and 150 MHz of processing bandwidth
6. A complete GPU-based signal processor for calibration, beamforming, correlation, and pulsar and transient searches

Challenges Commissioning the New Receiver

The commissioning proceeded in stages. With all new instrumentation, firmware, and software, the first tests of the system often included difficult troubleshooting. The front end cryogenics worked well but there were problems with overheating in the downconverter-digitizer electronics that required re-engineering of the receiver box. The digital fiber link used an unformatted bit stream technique in which the link clock and data stream lock were recovered from transmitted, digitized Gaussian noise. The first commissioning tests revealed an instrumental instability in which these digital streams would randomly lose lock. This was initially only observed on the telescope, and the troubleshooting involved testing elevation dependencies, cable and connector integrity, and signal amplitude dependencies to no avail. Attempts to reproduce the problem via ground testing were unsuccessful. The various electronics subassemblies were then retested individually. A voltage offset in the A-D converters was found and repaired but this alone could not have caused the problem. Finally, it was discovered that there were intermittent low frequency oscillations in the LNAs that, when coupled with ADC offsets, were the likely cause of the problem. The LNA low frequency oscillation was fixed by changing the bypassing on the LNA PCB, and by adding ferrite filtering to the voltage bias distribution. After these issues had been resolved, successful telescope testing ensued. The PAF receiver and digital downconverter were first commissioned successfully demonstrating seven simultaneous beams in each of two polarizations.

Further commissioning tests then demonstrated the digital backend with real-time correlator and beamformer. Work on the beamformer was predominantly done by students at BYU and WVU. BYU engineering students worked on the hardware and firmware developments, while astronomy students at WVU wrote the software for data collection and analysis. The teams collaborated on commissioning and

early science observations in 2017 and 2018. These included observations of a known pulsar and HI maps of a nearby galaxies (see figures).

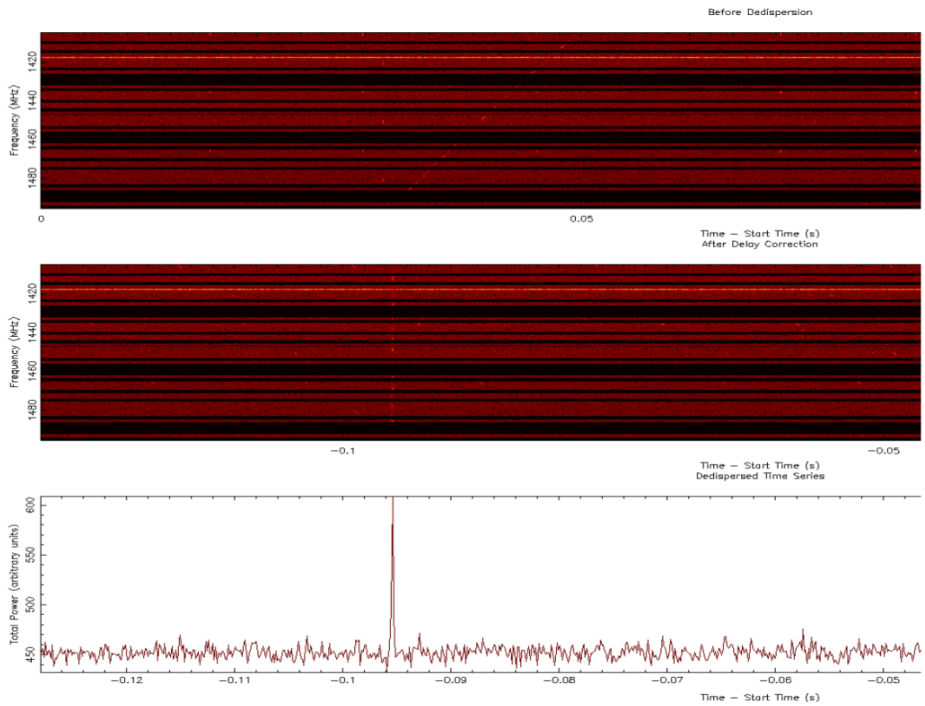

Figure 1 - The detection of a giant pulse from B1937+21 in one of the FLAG beams using the new beamformer.

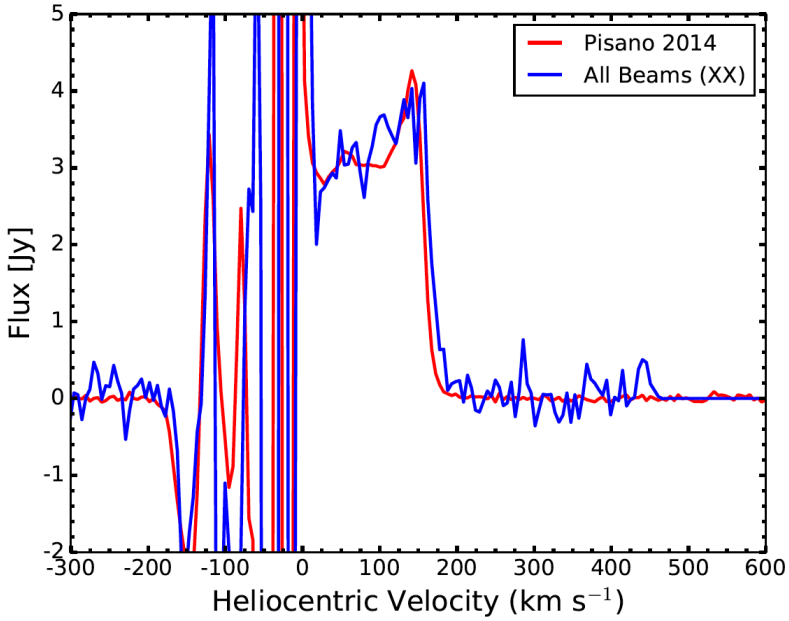

Figure 2- The atomic neutral hydrogen (HI) spectrum of the galaxy NGC 6946 from FLAG (blue) as compared to previous observations with the GBT (red). The agreement between the fluxes for the two receivers shows how well FLAG is working

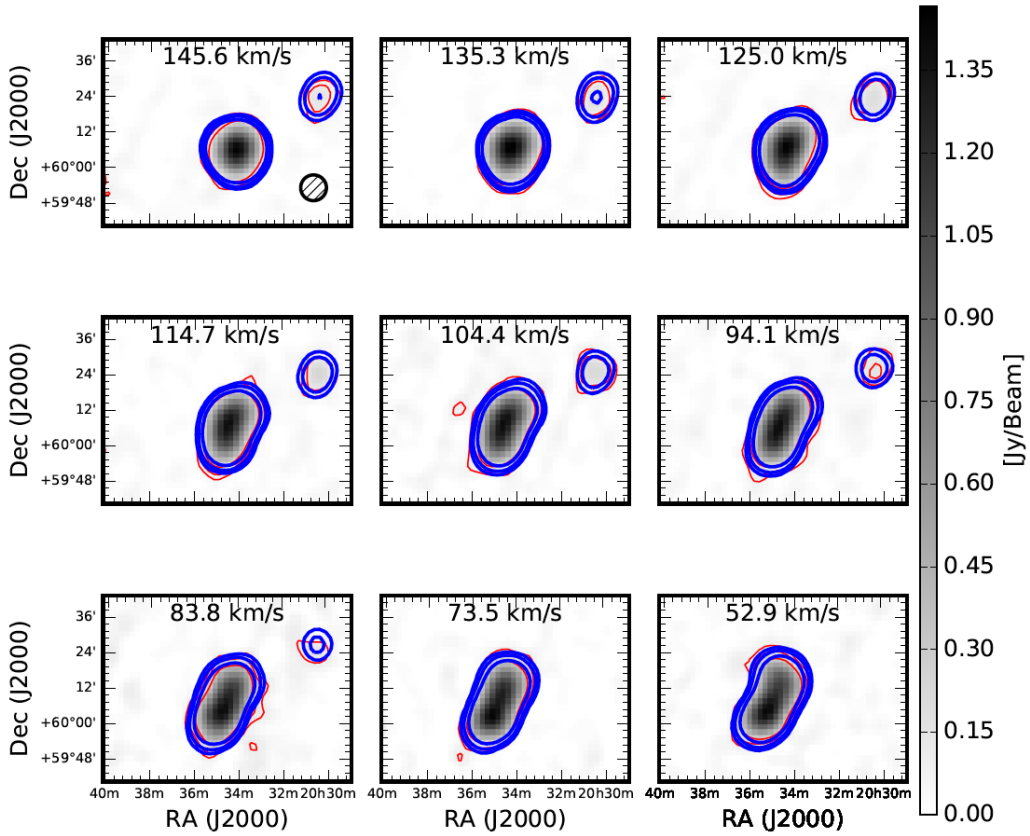

Figure 3 - Maps of HI as a function of velocity from FLAG (blue) and the existing GBT receiver (red). The agreement between the two datasets illustrate the excellent performance of FLAG. The existing data took 10 hours to collect, while the FLAG map was made in 30 minutes of observing.

Next Steps for North American PAF Development

With the successful commissioning of the FLAG receiver and the completion of the Beamformer backend, it is expected that the instrument will be available for GBT shared risk observations in upcoming semesters. Obtaining scientific validation of the FLAG/Beamformer system will be an important milestone for the technology. Cornell University, BYU, the University of Central Florida, and the Arecibo Observatory are now working on a new initiative funded under an NSF Mid-scale instrumentation grant, a 40-beam PAF called the Advanced Cryogenic L-band Phased Array Camera (ALPACA) for the Arecibo Radio Telescope.

When research on array feeds began more than 20 years ago, progress was slow. Early PAF prototypes had poor noise performance and low sensitivity. Strong collaborations between universities and research facilities, both within the U.S. and internationally, along with methodical prototype development and careful measurements and performance characterization, helped to overcome these challenges. The design process had to be adapted to account for antenna mutual coupling effects often ignored in other fields with less stringent performance requirements, and methods for experimental characterization of

complex, digitally beamformed arrays were developed [8]. These developments have brought the technology to the point that PAFs are now in use for wide-field astronomical observations.

Acknowledgment

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The National Radio Astronomy Observatory and the Green Bank Observatory are facilities of the National Science Foundation (NSF) operated under cooperative agreement by Associated Universities, Inc.

References

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[2] Fisher, J. Richard, and Richard F. Bradley. "Full-sampling array feeds for radio telescopes." *Radio Telescopes*. Vol. 4015. International Society for Optics and Photonics, 2000.

[3] http://www.atnf.csiro.au/projects/askap/news.html

[4] https://www.astron.nl/astronomy-group/apertif/news/apertif-news

[5] Jeffs, B.D., Warnick, K.F., Landon, J., Waldron, J., Jones, D., Fisher, J.R. and Norrod, R.D., 2008. Signal Processing for Phased Array Feeds in Radio Astronomical Telescopes. *J. Sel. Topics Signal Processing*, *2*(5), pp.635-646.

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[8] K. F. Warnick, R. Maaskant, M. V. Ivashina, D. B. Davidson, and B. D. Jeffs, *Phased Arrays for Radio Astronomy, Remote Sensing, and Satellite Communications*, Cambridge, UK: Cambridge University Press, 2018

Submitted by B. Shillue, K. Warnick, and D. J. Pisano

Job Postings – Radio Astronomy and Related Fields

University of Virginia

Assistant or Associate Professor in Astronomy (Astronomical Instrumentation)
https://jobregister.aas.org/ad/808842c2

Square Kilometer Array

Signal Processing Domain Specialist (Manchester, UK)
https://recruitment.skatelescope.org/domain-specialist-signal-processing/

Arizona State University – 3 Positions

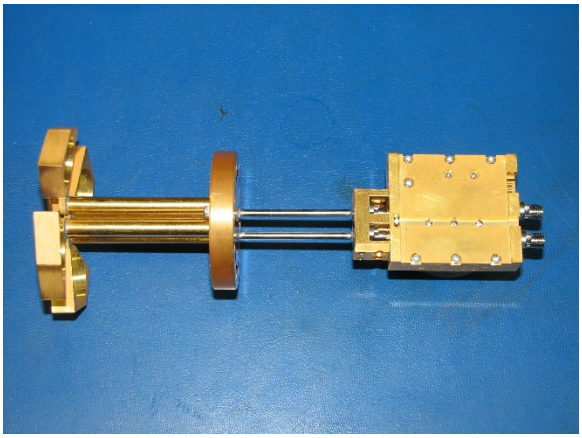
Research professional with expertise in radio-frequency engineering:
https://jobregister.aas.org/ad/a67137b8

Postdoc in Radio Instrumentation and/or Signal Processing
https://jobregister.aas.org/ad/6f5685cb

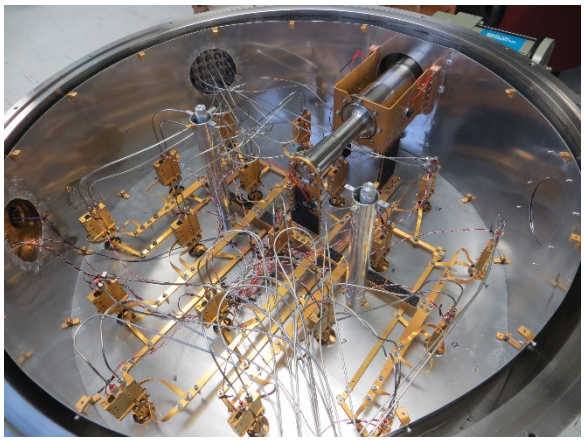
Postdoc in 21cm Data Analysis
https://jobregister.aas.org/ad/e56bb558

If your organization has an opening for a position that may be of interest to Commission J members please send the title, short description, and link for additional information to R. Bradley. Positions will only be posted by request from URSI members.

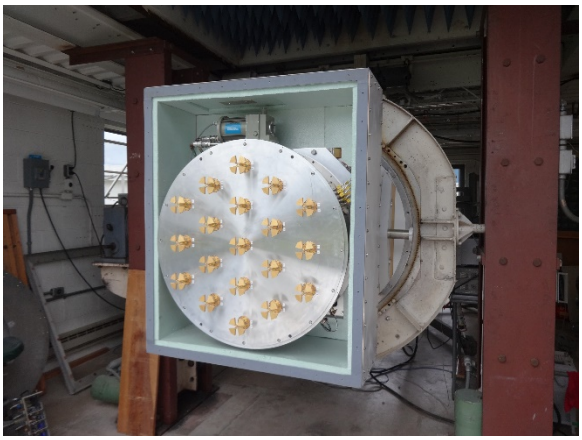
Photos from the Field – PAF Gallery



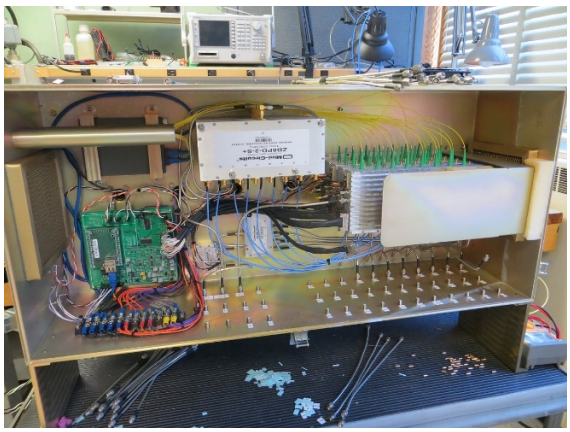
GBT2 Dipole and Low Noise Amplifier



Interior of Cryogenic Dewar



PAF Receiver in Outdoor Test Facility



40-channel Digital Downconverter

Receiver on Crane Hoist

Submitted by B. Shillue, K. Warnick, and D. J. Pisano

If you have an interesting photograph that you wouldn't mind sharing with others in the public domain I encourage you to send a copy to me along with a brief caption and the person's name or organization to whom I should credit.