A Day at Dwingeloo: Amateur Stewardship of a Historic Radio Observatory

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The author is CEO of the Open Research Institute (ORI), a 501(c)(3) nonprofit engaged in open-source digital radio and space communications. The site visit described in this article took place in September 2025 at the invitation of the C.A. Muller Radio Astronomy Station (CAMRAS) foundation. ORI has been a collaborator in CAMRAS's Earth-Venus-Earth (EVE) link-budget analysis since 2024.

Abstract: The 25-meter Dwingeloo Radio Telescope, inaugurated in 1956 as briefly the world's largest radio telescope, has been operated since 2014 by the C.A. Muller Radio Astronomy Station (CAMRAS) foundation. This is an active and vibrant volunteer organization of radio amateurs, amateur astronomers, engineers, and students. This article reports on a day of operations observed during a visit in September 2025. Activities spanned a range of professional-class radio techniques adapted to the amateur context. Pulsar observation and simultaneous 21-cm hydrogen-line monitoring enabled by a multi-consumer IQ stream architecture were followed by giant pulse detection from PSR B0531+21 (the Crab pulsar). Then, a radar-cross-section measurement of the Lincoln Calibration Sphere LCS-1. Finally, a three-site simultaneous Earth-Moon-Earth (EME) bounce at 1.2995 GHz using Zadoff-Chu sequences coordinated with Astropeiler Stockert (Germany) and the Allen Telescope Array (California). The operational model demonstrates a viable path for the continued productive use of aging scientific infrastructure. The EME experiments described are immediate preparatory work for the October 2026 Earth-Venus-Earth (EVE) campaign, which targets the next inferior conjunction of Venus. The goal of this Amateur Radio Service work is to receive a communications signal reflected from Venus, as opposed to a simple radar return.

1. Introduction

In a quiet corner of the northeastern Netherlands, near the edge of the Dwingelderveld National Park, stands a monument to an extraordinary moment in scientific history and to an even more extraordinary amateur renaissance. The Dwingeloo Radio Observatory, completed in 1956 with a 25-meter dish, was briefly the largest radio telescope in the world. This silver spiderweb helped map the spiral arms of the Milky Way and discover previously hidden galaxies. But this is not simply a story about a telescope. It is a story about what happens when professional science moves on, and amateur passion takes over.

The 1950s saw an explosion of radio astronomy. This was a time when the scientific community first began to see the true face of the universe. Construction at Dwingeloo began in 1954. When Queen Juliana inaugurated the instrument on April 17, 1956, it represented one of the most advanced efforts anywhere to listen to space. Using the 21-cm hydrogen line at 1420.4 MHz, astronomers mapped the spiral structure of the Milky Way with increasing detail and discovered the high-velocity clouds. These are rivers of gas streaming through interstellar space. The 21-cm radiation arises when the electron in a neutral hydrogen atom flips to align its spin with the spin of the proton, releasing a photon. Because hydrogen is the most abundant element in the universe, this line is a fundamental probe for astrophysics.

In the 1990s, during a survey of galaxies hidden behind the dust of our own Milky Way, Dwingeloo discovered a large nearby spiral galaxy, subsequently confirmed by infrared observations and named Dwingeloo 1. It turned out to have a companion, Dwingeloo 2.

By 2000, the telescope was no longer in professional operation. Radio astronomy had moved on to interferometers and large arrays. The Dwingeloo dish, once the world's largest, stood silent. At over 100 tons and accumulating rust, the future was very uncertain. This is where many stories of obsolete infrastructure would end. But not this one.

2. From World-Leading Professional Instrument to Amateur Renaissance

In January 2007, a group of enthusiasts established the C.A. Muller Radio Astronomy Station foundation, known as CAMRAS. C.A. stands for Cornelis Alexander Muller, one of the Dutch pioneers of radio astronomy. In June 2012, they physically removed the telescope dish for restoration. But CAMRAS did not restore Dwingeloo just to create a museum piece. They brought it back to active life.

Not just life for an insular few, but a place where people could learn and participate in real science and technical education.

What makes the Dwingeloo revival remarkable is not just technical. It is also cultural and philosophical. As radio amateurs know well, the word “amateur” comes from the Latin amator, meaning “lover.” To be an amateur in a pursuit is to have a passion for it. The CAMRAS volunteers are radio amateurs, amateur astronomers, engineers, students, and experimenters who have transformed what was once one of the world's premier professional instruments into what might reasonably be called one of the world's premier amateur instruments.

The recent achievement list is striking. CAMRAS has detected signals from Voyager 1, nearly 25 billion kilometers away in interstellar space, placing Dwingeloo among the few instruments in the world capable of receiving these faint carriers. Similar feats have been accomplished in the amateur community at Bochum Observatory in Germany, a 20-meter amateur telescope. And, the Deep Space Exploration Society (DSES) in Colorado, with its 18-meter dish, has its own deep-space ambitions.

In October 2021, a team including Thomas Telkamp, Jan van Muijlwijk, and Tammo Jan Dijkema bounced a LoRa IoT packet off the Moon. This was the first such demonstration using a small commercial RF chip (Semtech LR1110), setting a distance record of 730,360 kilometers [1]. In March 2024, Dwingeloo detected its first Fast Radio Burst, despite the fact that the receivers, built by radio amateurs, were not specifically optimized for the broadband signals characteristic of FRBs. In March 2025, Dwingeloo completed its first Venus bounce: a 278-second tone transmitted at 1299.5 MHz, with the echo successfully received both at Dwingeloo and at Astropeiler Stockert in Germany, yielding a clearly combined detection [2]. The first amateur Earth-Venus-Earth bounce was achieved in 2009 by AMSAT-DL at Bochum Observatory. Dwingeloo's 2025 success represented the second and opened the door to modulated experiments at the October 2026 inferior conjunction.

Radio astronomers, both amateur and professional, use the telescope for Earth-Moon-Earth (EME) communications experiments. Dwingeloo also conducts pulsar observations, participates in Very Long Baseline Interferometry experiments, tracks spacecraft, and contributes to citizen-science projects. The line between amateur and professional has become beautifully blurred. CAMRAS regularly opens the telescope to visitors, school groups, educators, amateur astronomers, radio amateurs, and other interested parties. What was once a temple of elite science has become a commons. It is a place where anyone with passion and curiosity can reach out and touch the universe.

This article documents a day at Dwingeloo hosted by Thomas Telkamp and attended by the author as part of an ongoing ORI collaboration with CAMRAS on Venus-bounce link budgets and digital protocol constructions for this very challenging radio channel. Thomas bridges the worlds of large-scale networking, amateur radio experimentation, and cutting-edge space technology. His career spans internet backbone engineering, satellite systems, and deep-space communications, and he was a generous and delightful host for the day.

3. A Day at the Telescope: Site, Startup, and Dish Health

The day's adventure begins in Utrecht, a short walk from the Dom Tower. Built in the 1300s, the structure sets a historical and cultural tone for the region that contrasts pleasantly with the high-technology destination ahead. Travel to Dwingeloo was accomplished by a combination of bus and car. The rich greens, browns, and grays of the tree-lined urban streets quickly gave way to the smoothly variegated greens of farmland and forest.

Arriving at the radio telescope feels a bit sudden. The gradually narrowing country lane bends around one last curve and ends in a small, tidy parking lot. At the top of the lot is a small house once occupied by the on-site caretaker. The building now serves as a restroom and meeting place for visitors and operators. Much like many modern fire observation and ranger stations in the United States, Dwingeloo no longer needs a live-in caretaker, but the infrastructure is still there. At the bottom of the lot, a short path leads directly to the telescope.

Fig. 1. Wheel carriage running on the circular track at the base of the 90,000 kg structure. Brushes on either side of the wheel sweep debris from the rail before each rotation. Every startup requires a careful walk-around inspection.

The 25-meter dish support structure rests on large metal wheels that run on a circular track. The telescope building, immediately below the dish, sits above the track and rotates with the telescope. The motor room is inside this building, off the hallway that connects the front door to the control room. With the wheels fully exposed at the outside perimeter of the structure, every startup requires a careful inspection and clearing of the track. At 90,000 kg, which is roughly the weight of a diesel locomotive, the telescope would easily crush anything left on the rail. Brushes are mounted on either side of each wheel to sweep away debris, but a walk-around inspection is still part of the protocol before every rotation.

We walked the track, then climbed the rain-slick metal stairs to the front door of the telescope building. It felt like boarding a ship or a large airplane. There are enough windows in the control room to see clearly that one is at least a story up off the ground. A skylight in the ceiling gives a direct view of the mesh dish and feed above.

Fig. 2. View through the control-room skylight showing the 25-meter wire-mesh reflector and the feed assembly at the prime focus. The mesh size is 8 mm, allowing the dish to operate from a few centimeters to a few meters in wavelength.

After setting down our backpacks and radio gear, the first task was to take the brake off and start up the motors. The engine room is small. There is enough space for perhaps six or seven people to crowd around the motors and gearing. There have been multiple changes over the years to the configuration of motors and gearboxes. The old infrastructure is still bolted in place beside the new. Because the entire building moves with the telescope, the power cables slowly wrap around the stationary main support shaft. Worst case, too many rotations in the same direction would cause the cables to wind up tight and break. The control software tracks cable wrap and will not let the telescope keep rotating past the point of damage, but it is considered good practice to unwind in advance of any long maneuvers or rotations planned for the day. Otherwise, an operator may be prevented from executing a planned observation and will have to spend time unwrapping the cables.

Fig. 3. Tammo Jan Dijkema (CAMRAS) and Thomas Telkamp (CAMRAS) inspect the main drive assembly after startup. The vertical shaft at top connects the rotating building to the stationary foundation; a monitoring system tracks cable wrap to prevent damage from over-rotation.

We were joined by CAMRAS volunteer Tammo Jan Dijkema, an engineer and mathematician with a keen interest in radio astronomy. With startup completed, we moved to the main control room. Tammo took one of the operating positions in front of the equipment racks and the large overhead monitor. Thomas began configuring the radio telescope. Tammo explained that when demonstrations are conducted for school field trips and public open houses throughout the year, the observations are recorded. These accumulated stores of sampled data allow Dwingeloo to plot Doppler differences of deep-space targets as they move with respect to the Earth over the course of a year. This long-term longitudinal study is itself a valuable resource for amateur radio astronomers.

Fig. 4. The Dwingeloo control room. The skylight directly overhead gives operators a line-of-sight view of the dish and feed. Equipment racks hold a combination of original 1956-era infrastructure and modern software-defined radio front ends.

When the scope slews, when it moves quickly between observation settings, one can clearly feel and see the building move and the dish rise or fall. When it settles down to observe at the same rate of rotation as the Earth (sidereal rate), the movement is subtle. One might notice only after a while that the view out the window has shifted.

Thomas has rewritten portions of the software that handles connecting to the telescope and summarizing status. This code is a modern, SDR-friendly update of professional software from the 1990s. A user interface for dish health and safety runs on one of the resident computers. The concern on this particular day was high winds throughout the region. The evidence had been visible all over the Utrecht city center. Leaves and limbs were scattered across sidewalks and at least one large branch came down at daybreak in the middle of a café. The Dwingeloo dish presents a large wind load, and above a certain wind speed the session would have to fall back to conservative objectives. Above a harder limit, the session would be cancelled entirely. The dish-health screen was mostly green, but yellow flashed intermittently. We would have to keep a close eye on this throughout the day.

Thomas described how the foundational 21-cm hydrogen-line surveys were continued in this very room. Against the backdrop of a large wall poster of one of those survey results, we connected an Ettus Research B210 software-defined radio to the telescope. The B210 has excellent receiver performance.

UHF and 13-cm operations are done with a manual patch in the equipment rack. With a laptop, the SigMF metadata format, and a modest amount of cabling, the entire universe comes to life from a Python script.

Thomas also described the ongoing effort earlier in the year to receive the carrier from the Voyager spacecraft. This is a challenging signal to receive, and the attempt highlighted by the difficulty of radio-frequency interference. Sources of RFI at Dwingeloo range from electric fences, which have been around for decades, to the relatively new disturbance of electric bicycles. Observational activities at the site fall into a few categories. There are natural objects and phenomena, human-made objects in space, radio-amateur communications experiments (EME, EVE), and educational outreach. Dwingeloo is also a SatNOGS ground station, and regularly contributes observations of satellites to the database under the amateur radio call sign PI9CAM (changed to PI9RD in November 2024).

Due to a happy travel coincidence, Paul Hearn and his wife Pam were able to join us. Paul and Pam were deeply involved in organizing the 2025 European Conference on Amateur Radio Astronomy (EUCARA25), held a few weeks prior. They described behind-the-scenes work and the inspirational keynote by Professor Jocelyn Bell Burnell, who discovered pulsars in 1967. It just so happened that Pulsars were on the target list for the day. We were then joined briefly by Ed Dusschoten, the chair of CAMRAS, who dropped by to make sure the volunteers had what they needed and to share some historical context.

4. Observations

Our first observational target was Cassiopeia A. Cas A lies in the plane of the Milky Way. We are looking at it through two arms of our galaxy, which produces a complicated and interesting spectral response. Thomas walked through the transmission and absorption features on the spectral display and identified the different galactic arms by Doppler velocity. The 21-cm hydrogen line was also being monitored live through the same IQ stream, producing the familiar profile visible on the right panel of the overhead monitor.

Pulsars are believed to be rapidly rotating neutron stars. These are what stars become when they run out of fuel and collapse. Instead of a fiery ball of gas, a neutron star is a ball of neutrons. Pulsars have very strong magnetic fields that funnel jets of particles along their magnetic poles, and when the poles sweep across Earth's line of sight we see the energy as periodic pulses, like the light from a distant lighthouse. Pulsar periods range from about 2 ms to many seconds, with the longest found so far rotating once every six hours.

Our next target was the Crab pulsar, PSR B0531+21. We were looking specifically for so-called giant pulses from this object. Since RFI can appear in these observations, it takes skill, patience, and quality software to weed out the RFI and leave only the true pulses. After some hand-editing of the Python analysis script to better capture the 33 ms period, Thomas explained an additional feature of the site's instrumentation that deserves attention. Conventionally, a stream of IQ samples (in-phase and quadrature complex baseband) is consumed by a single software program or instrument at a time. At Dwingeloo, Thomas has modified the software infrastructure to allow multiple consumers of the IQ data stream. This is a significant resource improvement. This means that several operators or experiments can share the same samples in real time. In practice this piece of software is what allowed simultaneous pulsar folding and 21-cm spectroscopy during our session.

With the setup confirmed, we watched the overhead monitor and waited. The “giant” pulses we were looking for arrive every few minutes. If a candidate event is a clean spike, it is probably local noise. If it exhibits the expected and predicted amount of interstellar dispersion, it is consistent with a pulse from the pulsar. After a while, a small collection of bursts at the right frequency and with the right dispersion appeared. Optimism grew, then became confidence. We had successfully observed giant pulses from the Crab pulsar. These are radio signals from about 6,500 years in the past. Signals produced today will not reach Earth until the year 8525. Pulsars are of more than scientific interest. Dwingeloo is one of the few sites where audio recordings of pulsars can be produced. The modern percussion composition “Le noir de l’Étoile” by Gérard Grisey is inspired by PSR 1919+21, discovered by Bell Burnell. The observatory is quietly engaged in the artistic side of its field as well as the scientific.

With giant pulses acquired as a warmup, our next target was something completely different. Instead of passively receiving energy from a distant natural source, we would receive energy reflected from an artificial satellite in low Earth orbit. The target was LCS-1, the Lincoln Calibration Sphere 1. This is a hollow metal sphere 1.12 m in diameter that has been in orbit since May 6, 1965, making it one of the oldest functioning spacecraft. The orbit is not expected to decay for another 30,000 years.

The radar cross-section of the sphere is very well known. The sphere was designed and manufactured precisely for that property, and its RCS was measured in L, S, C, X, and K microwave bands prior to launch. This allows ground stations to measure the performance of their systems by using LCS-1 as a reference reflector. With no transponders, translators, or repeaters involved, a passive metal sphere takes much of the guesswork out of characterizing a complicated radio system like Dwingeloo.

The quick motion of a LEO satellite crossing the sky, compared with the essentially stationary position of a deep-space object like a pulsar, requires the antenna to move faster in order to track. The higher the speed, the smaller the margin with respect to wind speed. Another constraint at Dwingeloo is that the dish can track a LEO orbit only up to about 40 degrees of elevation above the horizon; above that, there are complications and physical limitations. After a careful review of the dish-health screen (still showing green) and the projected orbit (below 40° maximum elevation), Thomas decided we would attempt LCS-1. The attempt was successful. The characteristic reflected return appeared on the spectral display.

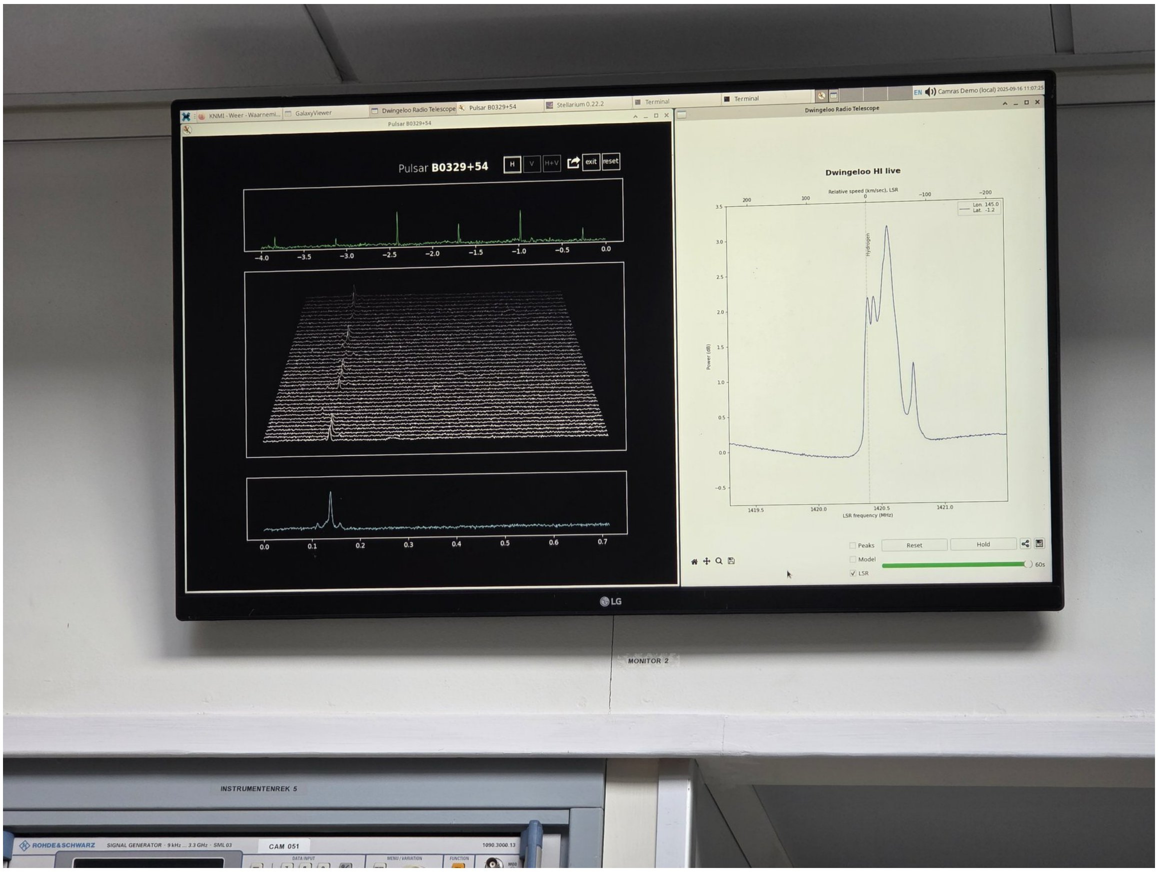

Fig. 5. Overhead monitor showing simultaneous instruments driven from a single IQ data stream. Left: folded pulse profile and waterfall for PSR B0329+54. Right: live 21-cm hydrogen-line spectrum in Galactic coordinates. The multi-consumer architecture allows several instruments to share the same sampled data in real time.

Thomas then took another careful look at the weather. Conditions were gusty at both Dwingeloo and Stockert, which was the partner site for an EME bounce scheduled that afternoon. The wind was forecast to improve. After some back-and-forth with Stockert, Thomas decided to move forward. The B210 was connected to a sequencer board, a solid-state amplifier, a power supply, and a large heat sink. Software-defined radios like the B210 do not produce enough transmit power on their own to drive radio instruments like the Dwingeloo transmitter. This type of instrument needs an amplifier to bring the signal into the 1-2 W range required by the downstream transmit chain.

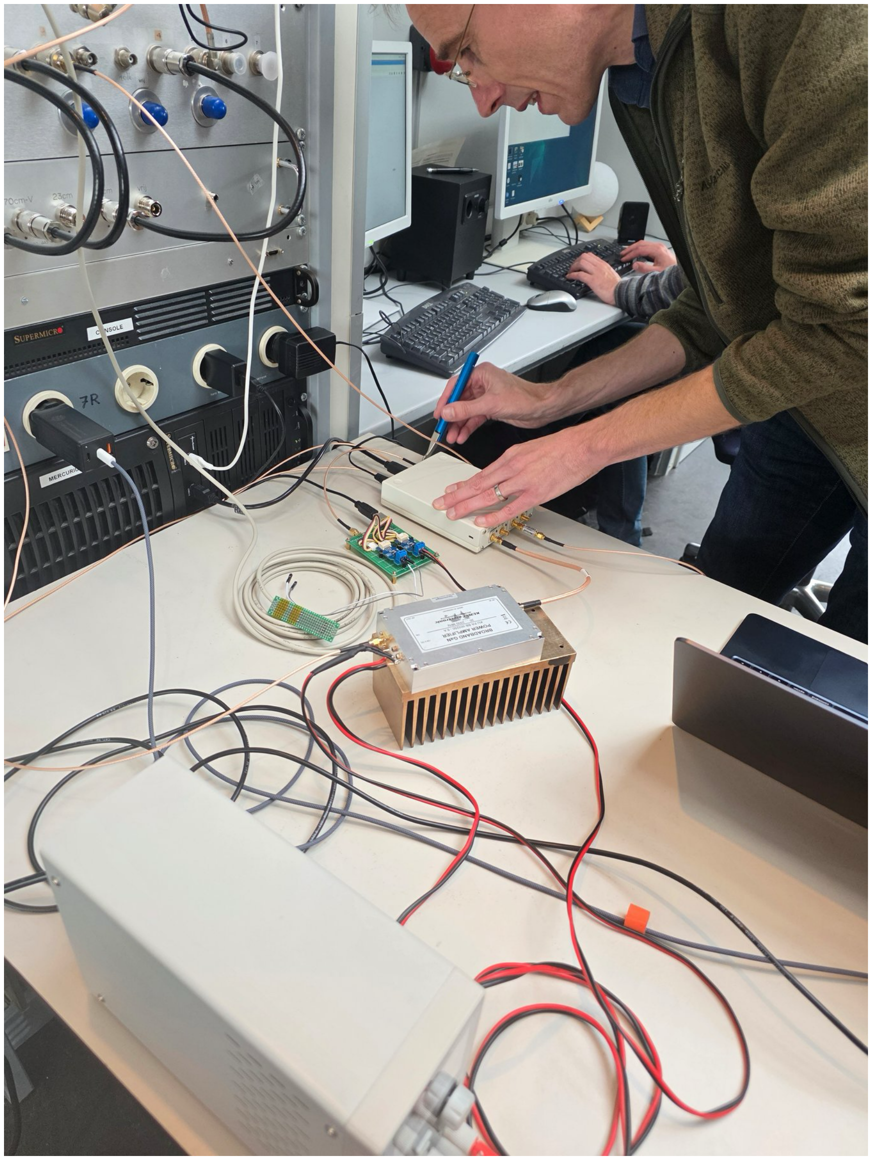

Fig. 6. Transmit chain for the Earth-Moon-Earth bounce. An Ettus B210 software-defined radio (white enclosure, right-center) drives a sequencer board and a solid-state power amplifier mounted on a large heat sink. The amplifier brings the B210 output into the 1-2 W range required to drive the Dwingeloo transmitter.

In order to display signals received from both sites simultaneously at Dwingeloo, Thomas set up a side-by-side waterfall on the overhead monitor. To get the receiver information from Stockert, he logged in over a VPN and opened an SSH tunnel back to Dwingeloo.

Transmit was tested and proven. The B210 amplifier was switched on, then the Dwingeloo amplifier, and ten sequences of 30 seconds were transmitted toward the Moon. Loud EME return signals were seen in the waterfall. The transmitted sequences included Zadoff-Chu sequences. These are coded transmissions being studied as candidates for EVE communication attempts in October 2026. Using EME as a testbed for EVE lets experimenters try DSP techniques and signal structures without waiting for Venus to approach close enough for an echo. Dwingeloo successfully received EVE carrier echoes in March 2025 during the most recent close approach of Venus [2]. Stepping up from carrier-wave detection to communications reception will require advanced DSP and carefully coded signals. Experiments like today’s EME bounce provide results and experience invaluable for an EVE attempt.

If coordinating two sites for live EME was impressive, then three was much more so. Thomas expanded the experiment by logging in to a citizen-science-accessible antenna at the Allen Telescope Array (ATA) at Hat Creek Radio Observatory in northern California [4]. A third waterfall was configured in software and displayed on the overhead monitor. We now had Dwingeloo, Stockert, and ATA receivers simultaneously watching the Moon for transmissions from a digital amateur radio experiment in rural Netherlands. And it worked. The return echo from all three sites was clearly seen and recorded at Dwingeloo. This demonstrated that the communications and logistics links between three of the most significant amateur and citizen-science radio-astronomy sites in the world were operational.

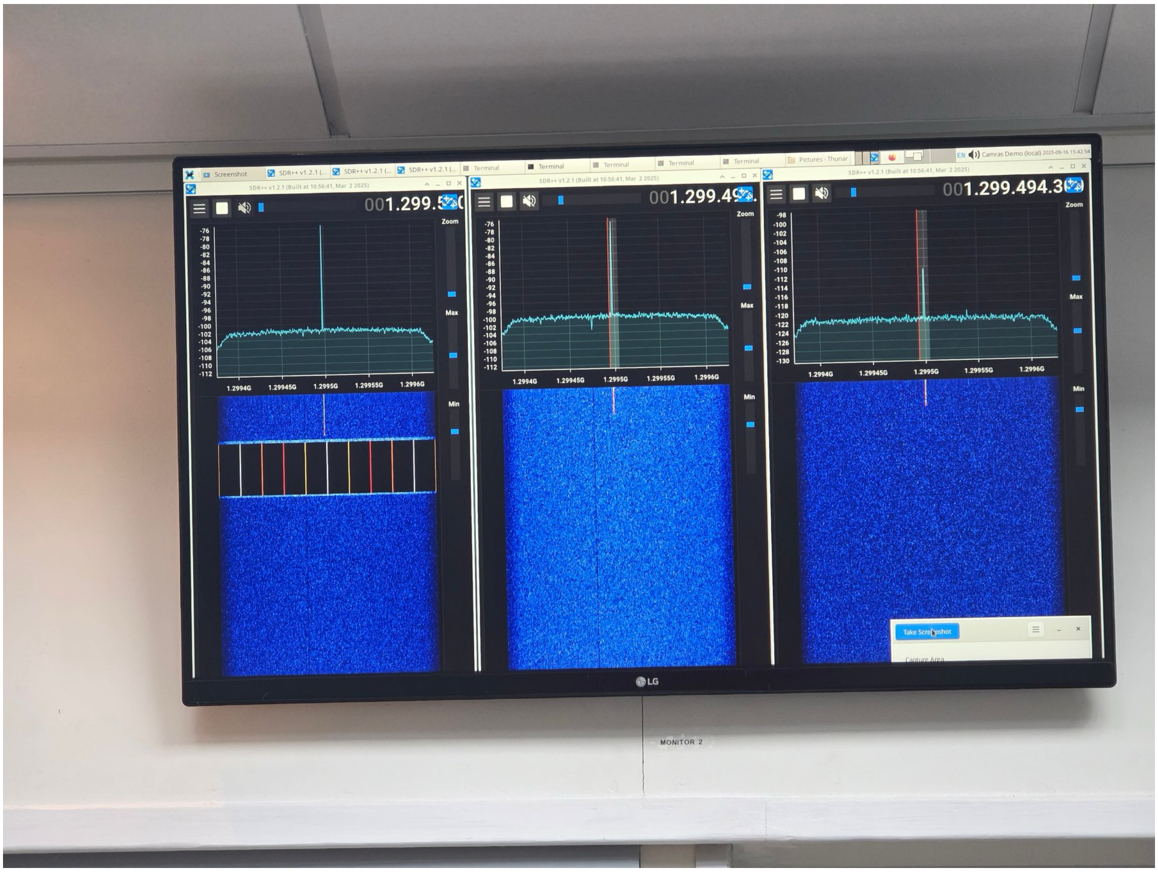

Fig. 7. Three-site simultaneous EME reception at 1.2995 GHz. Waterfalls from Dwingeloo (left, with the transmitted burst sequence visible in the lower half), Astropeiler Stockert in Germany (center), and the Allen Telescope Array in northern California (right). The vertical stripe in each panel is the lunar-bounce return from Dwingeloo's transmission.

5. Implications for the October 2026 Earth-Venus-Earth Campaign

The three-site EME experiment described above is part of a deliberate program of preparation for the Earth-Venus-Earth (EVE) attempts planned for the October 22, 2026 inferior conjunction of Venus. Unlike EME, for which the echo returns in about 2.5 seconds, an EVE bounce round-trip takes roughly 280 seconds at close approach. This requires long, coherent transmissions and careful Doppler tracking. The 2025 Dwingeloo-Stockert result [2] validated the carrier-detection path. Modulated signaling is the next step, and that step demands a signal design that is robust against the very low received signal-to-noise ratio and the chirp-like Doppler profile of an inner-planet bounce.

Zadoff-Chu sequences are a natural candidate. Their unit-amplitude, zero-autocorrelation-sidelobe structure makes them well-suited for synchronization and detection in CAZAC (constant-amplitude zero-autocorrelation) applications. They are the basis of LTE and 5G NR random-access preambles, for example. For EVE, the low peak-to-average ratio is beneficial at the transmitter, and the correlation properties are beneficial at the receiver. Pete Wyckoff of the Open Research Institute has performed Monte Carlo simulations of M-ary orthogonal signaling for this application. EME allows empirical cross-checks of those simulations in a real hardware chain without waiting for the next Venus conjunction.

Other candidate observations for October 2026 include ORI's ongoing link-budget work, which is validated against both the Bochum 2009 AMSAT-DL result and the 2025 CAMRAS measurement. A white paper published by the author earlier this year reported residual agreement of less than 0.1 dB between ORI's predicted carrier-to-noise ratio (in a 1 Hz bandwidth) and Thomas Telkamp's measured results at Dwingeloo, using a DC-centered integration methodology (±1 Hz around zero frequency after

Doppler correction). This close agreement raised confidence that modulated EVE experiments at the October 2026 conjunction are within reach of a coordinated network of amateur-operated instruments.

Dwingeloo's role in that network is central. The three-site EME experiment demonstrated that the end-to-end software chain (VPN access to remote sites, SSH tunneling of SDR sample streams, coordinated spectrum display) is ready for the coordinated operations that an EVE campaign will require. The multi-consumer IQ architecture at the site is well-suited to the kind of simultaneous processing that will be needed when a single 280-second transmission is analyzed by multiple demodulation pipelines in parallel.

6. Amateur Stewardship of Professional-Class Infrastructure

Closing down the telescope after so many successful observations was satisfying yet also bittersweet. The Dwingeloo story offers a template for how aging scientific infrastructure might be handled elsewhere. Rather than abandoning instruments when professional science moves on, we might recognize them as educational resources, platforms for citizen science, and tools that can continue producing valuable data in capable amateur hands.

The CAMRAS volunteers have shown that with dedication, creativity, and a collaborative spirit, amateurs can operate sophisticated instruments and make real contributions to our understanding of the universe. They have shown that the amateur spirit can be just as powerful a driver of discovery as professional funding and institutional support. The Astropeiler Stockert foundation [3] in Germany has demonstrated the same model, as have the Deep Space Exploration Society in Colorado and the Bochum Observatory team. The telescopes these organizations keep alive are all instruments that professional science had finished with. Yet these instruments remain productive, remain visible to the public, and in some cases continue to produce relevant and useful science.

In the shadow of the Dutch pine forests, where a 25-meter dish still turns toward the cosmos, the future and the past of science meet. Professional expertise built Dwingeloo. Amateur passion brought it back to life. And somewhere between those two efforts lies a truth about human curiosity that no amount of rust can diminish.

Acknowledgements

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