eCALLISTO Antenna

Solar Radio Telescopes (SRT) may be developed on a moderate budget in comparison with other solar instrumentation. Solar radio bursts associated with solar cosmic rays can be observed from Earth with radio equipment constructed using commercial components (spectrograph + antenna).

The eCALLISTO (Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory) network is a very effective scanning patrol device which relies upon geographical redundancy to maintain 24/7 monitoring of solar radio emissions. These spectrometers allow us to recognise the main types of solar radio bursts, like type III bursts as signatures of accelerated electrons and type II bursts as signatures of shock waves produced by flares or/and CMEs. Nevertheless, most of the CALLISTO-based telescopes have limitations in frequency and/or time resolution, and/or in sensitivity to study some kinds of faint radio emissions. These limitations are mainly due to low effective area of antennas and noisy locations of the stations.

The Radio Astronomy & Technical Special Activity Kollective (RATSAK) has developed a prototype eCALLISTO reciever and successfully proved its operation. In collaboration with the reinvigorated RATSAK, ASSA Council has agreed to support joining the international eCALLISTO network. The existing prototype receiver will be initially used as a testbed for a larger antenna installation, prior to upgrading the receiver and making a permanent installation of the spectrometer at either the Stockport Observatory or another site deemed suitable. Data from the spectrometer will be available to members in near real time via the internet from the Swiss Federal Institute of Technology Zurich (ETHZ Zurich).

RATSAK is committed to collaborating and implementing citizen science projects in a minimalist and environmentally friendly manner. Where possible, we try to think globally and act locally. As a consequence of this philosophy, we will construct our moderately large antenna, the front-end electronics and a tracking mount from locally sourced materials located here in SA. The receiver will be sourced from the Project Leader, Christian Monstein at ETHZ in Europe. The software is available for free from ETHZ under either EULA / free software licences and downloaded from the internet. Computer load is light to moderate and may be implemented on a variety of low cost, low power platforms such as notebooks or a Raspberry Pi Single Board Computer.

Antenna design

The antenna currently under construction is a log periodic dipole array (LPDA), a design which provides a moderate gain with a wide bandwidth and reasonable front to back ratio. LPDA antennas are often used as multiband television antennas. Inspiration for this LPDA was provided by the MRT1 developed at the University of Mauritius, for eCallisto reception. Mauritius has been operating MRT1 since 2011 in a fixed (transit) mode and while it has been superceeded by both the MRT2 and MRT3 antenna arrays, it still functions well and is simple to construct. The RATSAK LPDA is similar but follows standard design procedures where the length of the rear element is set for a frequency about 7% lower than the lowest design frequency and the upper frequency limit of the design is ordinarily set at about 1.3 times the highest design frequency.

For guidance, several texts were consulted to confirm the suitability of the LPDA for this task. A complete design description and supporting calculations were taken from the text “Modern Antenna Design 2nd Edition”. Dimesional calculations for the RATSAK LPDA were confirmed using the java script calculator(s) found here and here. The key characteristics used were:

- lowest (minimum) frequency = 92.5MHz
- highest (maximum) frequency = 1000MHz
- diameter of shortest element = 12mm
- characteristic input impedance = 50Ω
- relative spacing = 0.150
- taper = 0.900
- number of elements = 28
- maximum boom length $<$ 5000mm

Additional design tweaks may be incorporated during onsite testing in collaboration with local ham radio clubs/operators and some specialist test and measurement equipment.

Materials

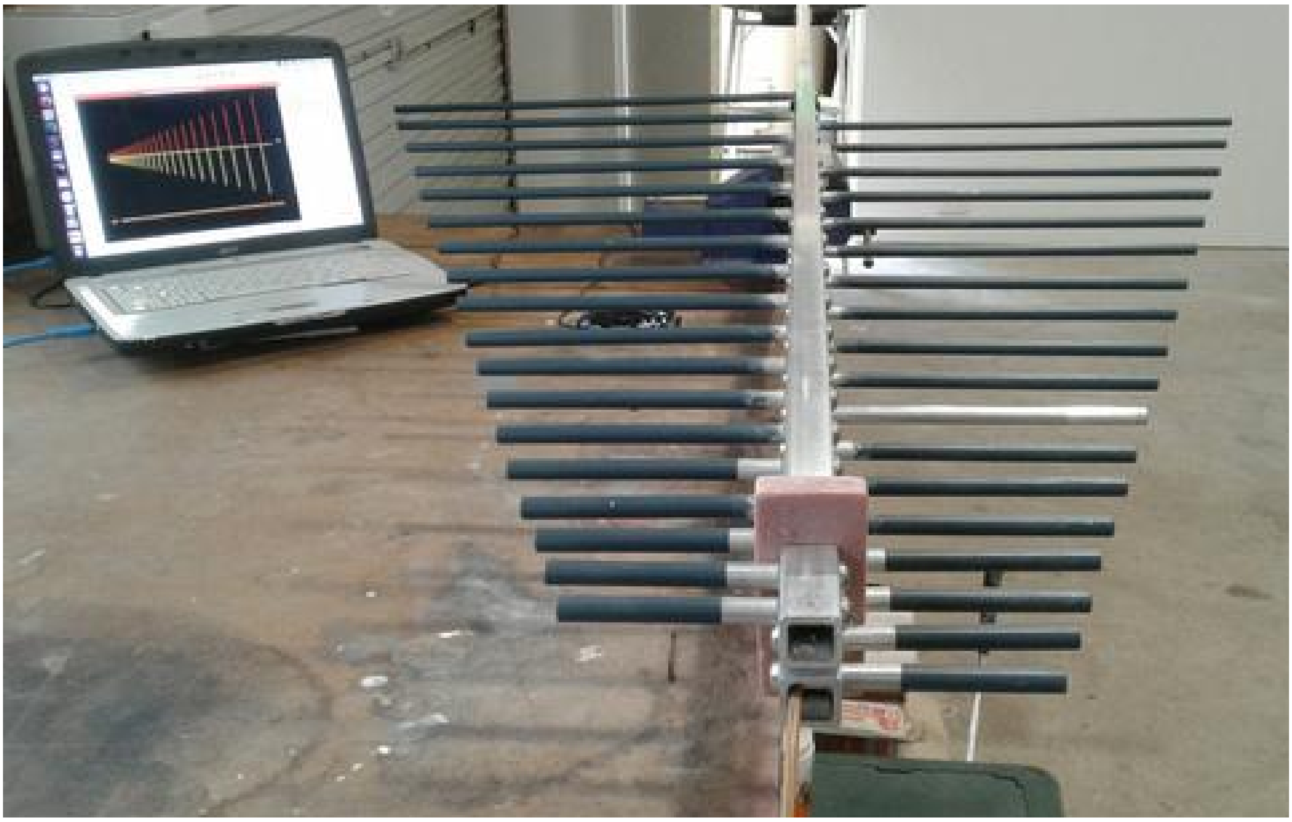
Basic 6060 grade aluminium materials selected for the LPDA were sourced from Capral in Kilburn, purchased as standard lengths of 6.5m (12mm tube) and 7.0m (25.4mm hollow square) stock. The heaviest (thickest) wall material was selected due to the lengths required. Aluminium is easy to work and cut in a garage or open area using basic hand tooling, some of which are shown in these images.

Due to the length and weight of both booms and elements, the structure needs to be constructed and fixed with materials suitable for outdoor conditions. The 12mm tube used for all elements has a wall thickness of 1.6mm, this makes the internal diameter of the 12mm tube approx. 8.8mm. Suitable machine screw sizes to suit a drilled hole of this diameter and tapped would be M10-1.25 or 3/8"UNF. Funnily enough, it's easier and cheaper to buy 3/8"UNF-24 pitch screws and taps in this country than M10-1.25 pitch, so that's what was used to fix each of the 28 elements to both booms.

To fix the elements to the boom, some additional length was added to the length of each element to compensate for the 25.4mm width of the boom and subtracting the 3.25mm boom wall thickness. The 12mm tube was cut to the required lengths, using a tape measure and a small diameter pipe cutter. One end of each element was filed out to allow the 3/8" tap to be inserted and cut a thread. Sellys RP7 was used as a lubricant for the tapping process (for want of something else) and each element washed in a solvent to clean out the threads when completed. Measuring and marking each of the booms for element placement was relatively straightforward using the calculated values obtained earlier. The only consideration was to offset the axis of the drill holes sufficiently to allow a coaxial cable to run inside one of the booms, from the base up to the feedpoint at the top. We should have sufficient space to allow a 5m length of 6.1mm OD low-loss cable such as Andrew CNT-240 to be used for the feedline. At each element location, a 2mm pilot hole was drilled at each point through opposing walls of the 25.4mm hollow square extrusion. One wall was step drilled out to 3/8" and the opposite wall step drilled out to 12mm, then all the holes deburred, inside and out.

Spacing the booms

The LPDA design requires that each boom is insulated from each other at the top (feedpoint), along the length of the booms and shorted together at the bottom with a stub. Should you care to take your multimeter and make a resistance or continuity measurement between each boom, you will get a short or close to 0Ω. As this is an antenna made for radio frequencies, impedances change with wavelength. What you see with a multimeter at DC (0Hz) does not apply in the hundreds of MHz region of the EM spectrum. So we need to construct some insulators, primarily to keep the booms physically isolated and keep the elements aligned.



There is also a requirement to maintain a tapered spacing between the booms, beginning at the feedpoint, all the way down to the stub at the base of the antenna. These insulators need to be made from a material with good ultraviolet (UV) radiation characteristics and sufficient strength to hold the LPDA structure together in all weather conditions. To provide adequate strength, 25mm High-Density Polyethylene (HDPE) was selected as our preferred choice because it is readily available in rectangular sheets and relatively easy to cut and mill. A linear taper from 3.5mm (feedpoint) to 45mm (stub) is made by four insulators spaced approx. 1.2m apart, centred on the balance point of the antenna. This also allows us to create an electrically isolated and workable coupling to connect the antenna to the solar tracking mount. We were fortunate to have ASSA member Alan Brinkworth willing and available to manufacture the four insulators for us and we remain in his debt for his assistance with this task.

Some images shown here have a prototype insulator made from fibreglass car bog which was prone to inconsistancies in density and not considered suitable to the task.

Assembling the antenna

After deburring each hole, the first four elements were fixed using the 3/8"UNF x 1" button head socket screws, a small amount of Loctite 243 Threadlocker and a 7/32" hex (allen) key wrench. The smallest of the 25mm spaced insulators was fitted to the antenna assembly and the fifth element pair added. The process is repeated for another 15 element pairs where the next insulator is fitted between the 19th and 20th elements. The third insulator is fitted between the 24th and 25th element pairs, the final insulator slips in just above the 28th and final element pair. Once assembled, the booms should look largely identical but opposite, apart from the coaxail cable hanging out of the lower boom.

Feeding the antenna

A common method of connecting a low impedance, wide bandwidth LPDA is to use an infinite balun. An infinine balun does not require an impedance matching transformer and works by running the coaxial feed along the length of the boom, the booms acting as a transmission line. The shield of the coaxial cable is terminated at the top of the lower boom and the centre conductor of the coaxial cable is terminated at the top of the upper boom.

Both terminations need to be mechanically and electrically sound and protected from the weather, the effects of ultra-violet (UV) radiation and curious wildlife, primarily birds. The area surrounding the termination has been encapsulated with a long life silicon compound, housed in a UV stabilised casing
(a 65mm DWV pressure pipe cap).

Terminating the antenna with a stub

The final assembly task is to create a terminating stub at the base of the antenna. A stub of ¼ wavelength of the longest element (405mm), provides several benefits to the antenna design and adds to its practical survivability, once deployed.

The stub largely eliminates the possibility of static build-up on the antenna and eventual static discharge, which would probably destroy the sensitive low noise amplifier (LNA) located in the following stage, the front end electronics package.

Future articles will briefly describe the front end electronics, the spectrometer, the integration and physical installation of the SRT.