3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Designs for Proof of Concept Shape Memory Alloy Antennas in Space

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In this paper the research the design of an Shape Memory Alloy Yagi-Uda and Horn antenna is presented. With the recent launch of the James Webb Space Telescope, a new research device has started to answer the question when the first stars and galaxies were formed [1]. Going even further back, there is the time of the Dark Ages, just after the Big Bang. It is expected that the signals originating from the Hydrogen atoms of the Dark Ages, the epoch of reonization, are redshifted towards 80 kHz - 30 MHz. This research is performed the latter design context.

Unfortunately, these measurements cannot be done from the Earth due to a combination of severe ionospheric distortions, the complete reflection of radio waves below 30 MHz and radio frequency interference (RFI). It is therefore needed to design a radio telescope for space. This is done under the name of OLFAR [2]. By combining 50-1000 of these antennas on small satellites, it is possible to create a virtual radio telescope using interferometry. However, each of these satellites need a small volume antenna that also need to be sensitivity to receive these 13 billion year old signals. A solution for an automatically deployable antenna with an advanced design is Shape Memory Alloy. This metal can be trained to a certain shape. After cooling down, SMA is known by its ability to be deformed and to recover to its pre-trained shape by heating it to a certain transition temperature.

Two antennas were simulated [3], constructed, deployed and measured for a proof-of-concept satellite. Both antennas fit within 0.5U (10x10x5 cm) when stowed. The first antenna is a Yagi-Uda operating at 1420 MHz (21 cm Line) used for science observations, made of wire material and stowed by folding it over itself (Fig. 1). The other antenna, is a horn antenna for the communication downlink to Earth, operating at Ku-Band (12-18 GHz). During launch, the four solid sides of the horn antenna would be rolled down (Fig. 2).

Experiments were done on the antennas by heating them with a hot air gun. In terms of deployment, the Yagi-Uda antenna shows a deployment from 50 to slightly less than the ideal 400 mm, meaning a recovery of over 95%. Measurements show that the gain compared to simulations (10.1 dBi), the ideal and deployed antenna achieve only 2 and 2.2 dBi less. The horn antenna, on the other hand, with an full height of 200 mm on the hand was deployed and measured in steps as the plate material for the sides was seen to be unreliable in deployment. Only a recovery of around 60%. An average gain difference over the band between ideal and full deployment was around 4 dBi. This was decreased to 2.5 dBi by further improvements.

The results show that there is great potential in the usage of Shape Memory Alloy for radio astronomy, but also for antenna design and reconfigurability in general. Although the deployment for the horn antenna was not completely successful, with further experiments and different thickness material this can be solved. Further research can now focus on the design of more advanced and complex structures as with these experiments a proof-of-concept has been shown to work.

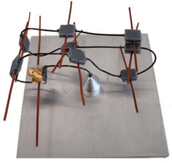

Figure 1: Stowed Yagi Uda Antenna

Figure 2: Stowed Horn Antenna

References

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