

*Q & A to:*

## **Kilometer-square Area Radio Synthesis Telescope – KARST**

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**Q:** Can the authors give their reasoning of how the “small-N” KARST SKA implementation might achieve the specified imaging dynamic range for the SKA?

**A:** The specified imaging dynamic range of  $10^6$  @1.4GHz for the SKA is clearly a challenge for synthesized radio telescope array. For arrays with “small-N”, the best imaging performance might be achieved with optimum uv-coverage configuration and good calibration in the data post-processing procedure. One example is the VLA , where the 27 elements are strategically placed to form a “Y”-shaped array to gain better uv-coverage. Some experiments with the VLA have indicated that a dynamic range of up to  $10^5$  might be achieved with careful phase and amplitude calibrations.

In the case of the KARST SKA, although the locations of the depressions are fixed (refer to p3 of the concept white paper), the uv-coverage could still be somewhat optimized by making careful selections among the available karst depressions. The KARST SKA consists of about 30 elements, which is similar as that of the VLA. And with a diameter of each element about ten times larger, a higher imaging dynamic range is expected when a strong compact source with no complex structures is observed with the KARST. The KARST could handle most of the SKA key scientific objectives, e.g. the neutral hydrogen at high redshifts and some transient phenomena of short time scales like pulsars and variable stars, where large collecting area is of the prime importance. While observing complex extended sources, the KARST might run into the dynamic range limited imaging problem because of the sparse uv-coverage resulted from the “small-N”. Further improvement on the imaging quality would be expected with better phase and amplitude calibrations in the future.

On the other hand, it should be noted that the “small-N” SKA implementation has some advantages. The small number of elements allows the best receivers to be equipped. In the KARST case, there is enough space for the best receivers of each observing band. While in the “large-N” solution, the number of feeds is large, and the space for the feeds are relatively small, thus wide-band receivers are preferred. The contemporary wide-band receiver normally performs poorer compared with the rather narrow-band receivers dedicated to each band. Secondly, the “small-N” solution also reduces the complexities in the data-transmitting and correlating facilities compared with the “large-N” solutions.

**Q:** The KARST concept as presented falls well short of the SKA target of 1 Deg<sup>2</sup> field-of-view at 1.4 GHz. With a 200 m reflector, the beam area is around 0.01 Deg<sup>2</sup> and at least a hundred beams would be necessary to meet the target. Would such a system be feasible in the existing design, given the reflector optical parameters and the implications on e.g the weight at the focus? Would the authors speculate on the cost of extending KARST using focal-plane arrays?

**A:** Yes, one feasible way to realize the specified 1 Deg<sup>2</sup> field-of-view for the KARST is to

use focal-plane arrays. According to the existing design for KARST concept, the receivers are mounted on a stabilized platform with a diameter of 4 m. The allowable weight load on this platform is about 3000 kg. The L-band multi-beam receiver would be located at the center of the platform. This L-band receiver might be replaced with a focal-plane array. Given the space available for a focal-plane array and the optical parameters, a simple geometrical optics (GO) consideration implies a FOV of about  $0.5 \text{ Deg}^2$  might be achieved under the current design (Fig. 1).

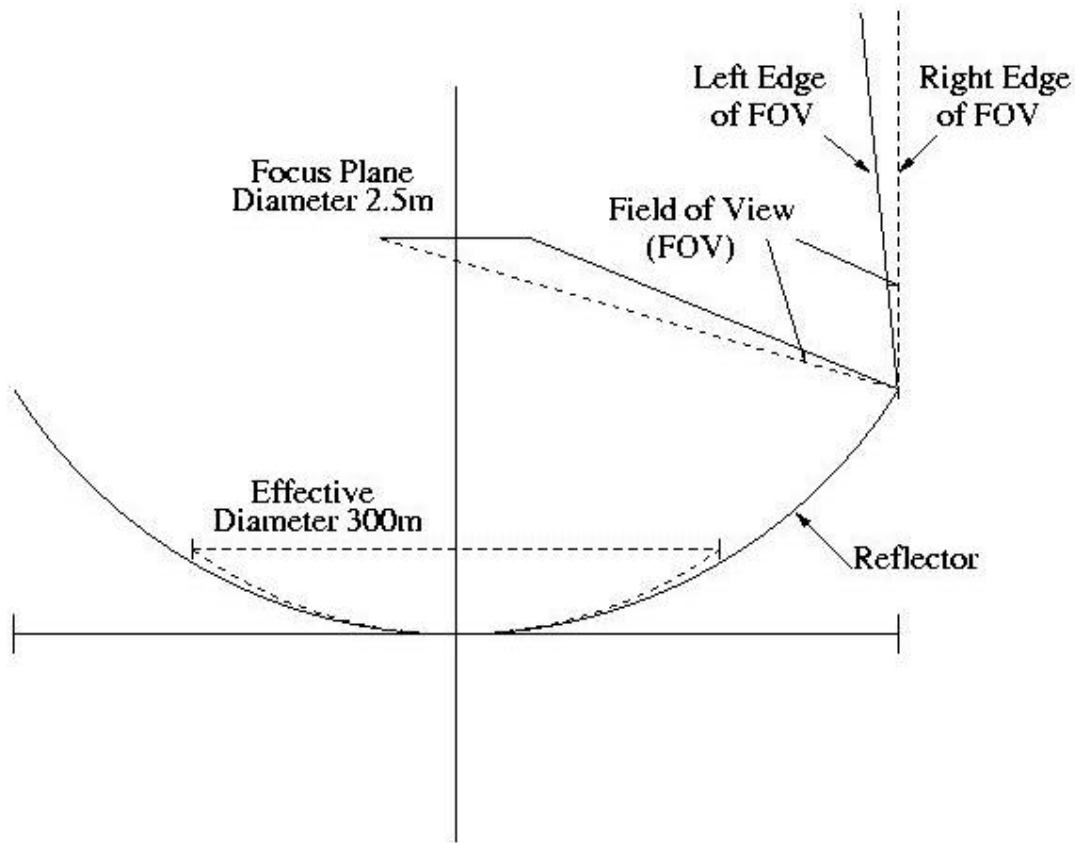


Fig. 1 The FOV achieved by using a focal-plane array (via GO analysis).

We have started a feasibility study of using a focal-plane array for the KARST. Compared with the LAR concept, where the  $f/D$  is larger and the focal length is longer, our KARST concept has smaller  $f/D$  and much shorter focal length, thus the Focal Field Distribution (FFD) would be more complicated. On the other hand, in order to realize the same FOV, a much smaller focal-plane array is required. The preliminary results of the FFD analysis for the KARST showed that it is feasible to enlarge the FOV by using a focal-plane array, and confirmed the FOV of  $0.5 \text{ Deg}^2$  implied from the simple GO considerations as mentioned above. Considering the relevant cost issue of the LAR and the AAT, 5 M Chinese Yuan ( $\sim 0.6\text{M USD}$ ) might be needed to implement a focal-plane array. Further extension of the FOV might rely on a larger focus cabin.

**Q:** The lowest operating frequency mentioned is 300 MHz but presumably the antenna can operate down to 100 MHz with suitable feeds. Could the authors confirm that size and weight constraints at the focus permit the use of larger feeds?

**A:** The arrangement of the feeds in the focus cabin is very flexible. According to the existing design, the receivers are mounted on a stabilized platform with a diameter of 4 m.

The allowable weight load on this platform is about 3000 kg. Considering some existing design of the 100 MHz feeds, e.g. the feeds used at the VLA and Dickiy type, there is no problem for KARST to use such feeds to operate down to 100 MHz.

**Q:** The authors nominate a suite of narrowband receivers for KARST. Do they feel that contemporary wideband receivers and feeds may have a role in simplifying the proposed antennas?

**A:** Yes, the use of wideband receivers will simplify the proposed antenna. But there are still some shortcomings, e.g. the contemporary wideband feeds (e.g. the ATA feed) normally could not give equally satisfied illuminations across the whole band, while the current narrow band feeds and receivers would perform better. According to the existing design, the space and weight constraints of the focus cabin could accommodate a suite of narrow band receivers. And the “small-N” of the KARST also results in that the investment on the feeds and receivers would only take a small part of the total cost. So we have adopted the suite of narrow band receivers in the current design to gain better performance at each observing band. It is no doubt that the wideband technology will be chosen if the performance of wideband receivers and feeds will compete that of the narrow band in the future.

**Q:** Can the authors give an indication of typical source-change times, bearing in mind the composite performance of the various mechanical systems?

**A:** According to the current design of the KARST, the source-change is realized via the combined movement of the focus cabin driven by a series of cables and the actively actuated main reflector. Unlike the traditional E/A mounting type, no cable-wrapping is needed, thus source-change time is mainly determined by the source-separation on the sky. Consider the largest separation within the sky coverage (refer to p3 of the concept white paper), the source-change time would be about 10 minutes, for smaller separation shorter time is needed.

### **Additional Questions:**

Could the authors give a brief outline of any links they see between their concept and potential SKA sites? Issues to consider include:

**Q:** requirements or limitations associated with particular terrain and climate (e.g. need for a given terrain, susceptibility to snow, ice, temperature extremes, high winds, hail and lightning)

**A:** In the south-west part of China, there are an area spreaded with plenty of karst depressions. These depressions are very similar to the terrain of the site where the Arecibo telescope was built about 40 years ago. Based on this available terrain, Chinese radio astronomers have conceived the KARST SKA concept, which is a synthesis array consists of about 30 elements, and each element is an innovated Arecibo-like telescope build in one of the karst depressions. We have evaluated the karst depressions in that area, and in particular, carried out extensive inspection in the two counties (Ping Tang and Pu Ding) in

Guizhou province. Based on the typical climate data of the karst depressions in these two counties, we have carried out a feasibility study of building a Five hundred meter Aperture Spherical Telescope (FAST), which serves as a prototype of an element for the Chinese SKA concept KARST. In this aspect, the karst depressions in Guizhou province is part of the Chinese SKA concept. And any other site that has similar terrain and climate would meet the needs of the Chinese SKA concept KARST.

**Q:** approximate energy requirements for central array and remote stations

**A:** According to the current design for the KARST, the element with large diameter would require more energy, but the energy requirement for each element are essentially at the same order. For an element with a diameter of 500 meter, the amount of energy required would be about 400 kW. For the central array consists of about 20 stations, the energy requirement would be about 8000 kW. And for the remote stations (about 10), the energy requirement would be about 4000 kW. The total energy requirement for the whole array would be about 12,000 kW.

**Q:** requirements related to RF environment (e.g. level of radio quietness demanded by basic system dynamic range)

**A:** The natural terrain in the Ping Tang and Pu Ding counties would to some extent shield ground-based RFI, together with the fact that it is a less developed area, the site would have natural immunity to the ground-based RFI. In particular, the local government has shown interest in the SKA project and established a radio quiet zone following the ITU regulations. This measure will greatly protect the RF environment in this area, thus ensure potential radio astronomy development in this area in the near future.

**Q:** requirements for data processing and transport, including any need for local large-scale data processing or aggregation, as well as typical demands on international communications infrastructure (e.g. trans-oceanic fibre)

**A:** According to the current design, an extended version of contemporary correlator technology could be adopted for the array. And for the data transport from the stations to the correlating center of the array, a local optical fiber network is desired. When a focal-plane array is used to enlarge the FOV for each element, a large scale data aggregation at each station might be needed. In such case, the data transport rate from stations to the correlating center would be much larger. The correlating center would have a direct data link to the nearest downtown. If the array would attend e-VLBI observations, in which the observed data need to be transported to the VLBI correlating center in real time, this data link to the nearest downtown might also serve for this purpose.

**Q:** SKA Science Matrix at [http://www-astro.physics.ox.ac.uk/~sr/ska/ska\\_matrix.html](http://www-astro.physics.ox.ac.uk/~sr/ska/ska_matrix.html)

**A:** KARST SKA received low scores (Red color) in many of the items listed in level 1 science mainly due to the lack of long baselines of more than 2000 km, which we do not think is critical to any SKA concepts to do key science such as the pulsar.

Each element of the KARST SKA has a large collecting area, therefore has very good raw sensitivity, and would have low data reduction loss compared with the “large-N” solution. The KARST SKA would perform well in observing low brightness, diffuse emissions, and transient phenomena like single/individual pulse of pulsar.

According to the current design, the FOV of each element is small, which makes it ineffective in surveying observations. But the application of the focal-plane array would greatly improve the KARST FOV, and make the KARST SKA potentially capable of handling most of the following observations. We have been working on such a solution, and would like to bring some suggestions to the ISAC for considering some modifications on KARST to the present version of SKA compliance Matrix:

1 Galactic HI	Yellow
2 Transients	Yellow
2 Pulsars	Yellow
2 SETI	Yellow
4 Continuum surveys	Pink
5 High-z AGN	Light blue
5 Inner AGN	Dark blue
6 Protoplanetary systems	Pink