32nd URSI GASS, Montreal, 19-26 August 2017

Radio Telescope Cost Modelling using Performance Measures, Cost Scaling Rules, and Total Cost Constraints

A.J. Boonstra*(1), R.J. Nijboer(1)

(1) Netherlands Institute for Radio Astronomy (ASTRON), PO Box 2, 7990 AA Dwingeloo, NL

Extended Abstract

Radio telescope designs usually aim at supporting multiple science cases, each corresponding to a particular figure of merit (FoM) [1,2]. These quantities may for example be based on sensitivity (FoM_s) or the speed with which a particular survey can be carried out, the so-called survey speed (FoM_{ss}). System parameters driving these figures of merit include the system noise T_{sys} (K) of each telescope, the effective receiving area of each of the telescopes A_{eff} (m^2), the observation bandwidth B (Hz), the integration time τ (s), and the field of view Ω (Sr). From the actual FoM formulas for sensitivity and survey speed, shown below, it can be seen that they scale differently for different system parameters.

$$FoM_s = \frac{A}{T_{sys}}\sqrt{B}\,, \qquad FoM_{ss} = \Omega\, B \left(\frac{A}{T_{sys}}\right)^2 \tag{1}$$

When designing radio telescopes, the final telescope sizing, array layout, and processing architecture is usually obtained after a few design - costing estimate cycles. In this process the figures of merit play a central role. An alternative approach or view would be to find optimal figures of merit in terms of cost. In this approach costs are assigned to the different parameters such as T_{sys} and B. Given a fixed total cost, an optimal distribution of costs over the system parameters can be computed using Lagrange multipliers. For example, assuming a fixed T_{sys}, define a cost function C as follows:

$$C = \alpha A + \beta B \tag{2}$$

where C is the total cost of the instrument (€), α is the cost of the antenna aperture per square metre (€/m^2), and β is the cost of the (back-end) bandwidth per Hz (€/Hz). Using these simplified assumptions, Lagrange multiplier optimization would lead to the conclusion that for FoM_s two-thirds of the cost should be spent on the aperture, and one third on the (backend) bandwidth. For FoM_{ss} this would be fifty-fifty. Somewhat surprisingly, these distributions of cost are not dependent on α or β.

A more realistic and useful approach would be to refine the cost functions by including scaling parameters such as the number of telescopes. This approach is applied to the LOFAR telescope design, and compared with the actual cost distribution. This will be presented, together with an analysis of the costs for a subset of the SKA telescope parameters.

Acknowledgement: this work is inspired by Jaap Bregman, and is conducted in the context of the Dome project supported by the Dutch Province of Drenthe and the Ministry of Economic Affairs.

References

1. J.D. Kraus, Radio Astronomy, Cygnus, Quasar Books, second edition, 1986.

2. J. Cordes, "The Square Kilometer Array as a Radio Synoptic Survey Telescope: Wide field Surveys for Transients, Pulsars and SETI," SKA Memo Series, vol. Memo 97, pp. 1-41, 2009.