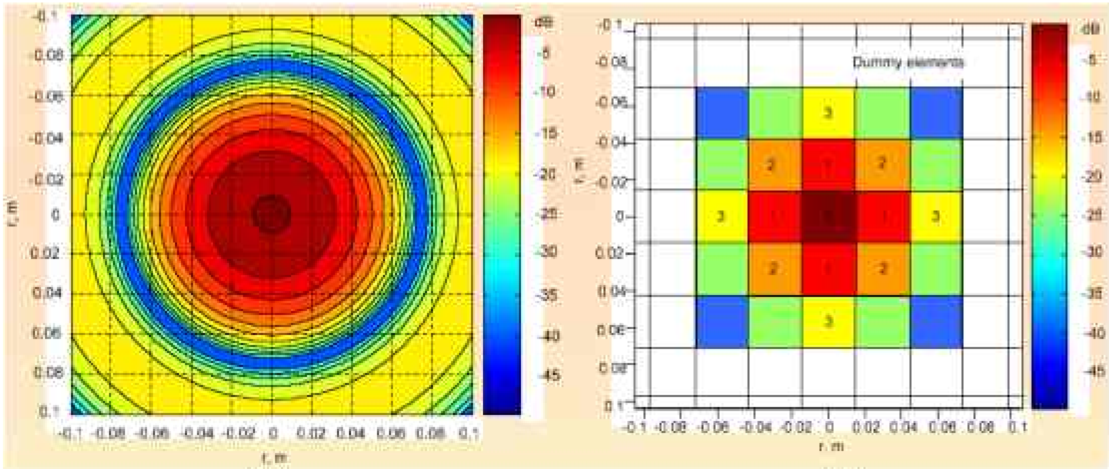
[Emerging Device Technology](#) > **Focal Plane Arrays for Radio Astronomy**

This work is funded throught the Europen comission and is doen with partners across Europe. The aim the project is to generate the technology for affordable, low-noise, phased receiver arrays to be installed at the focus of large radio telescopes. In a phased array, the receivers are interconnected so that multiple beams can be synthesized and steered electronically. By collecting and then manipulating the fields in the focal plane, such arrays can simultaneously offer improvements in efficiency and effectiveness of existing telescopes and open up the wide possible field-of-view.

The photograph of a radio telescope is shown in Fig.1. When the telescope is pointed towards a target in the space, radio waves arriving from the target are intercepted by the reflector and reflected from the big dish into the focus box mounted on top of the central tower. Here, at the focal plane of the reflector, a small aerial picks up the waves and feeds them into a sensitive radio receiver. In order for the receiver to perform at low noise, the front-end RF electronic devices, such as the aerial and the low noise amplifiers, are cooled down to cryogenic temperatures, usually below 20 K.

Fig. 1 Photograph of the Lovell Telescope at the
Jodrell Bank Observatory, Manchester, UK (taken from [1])

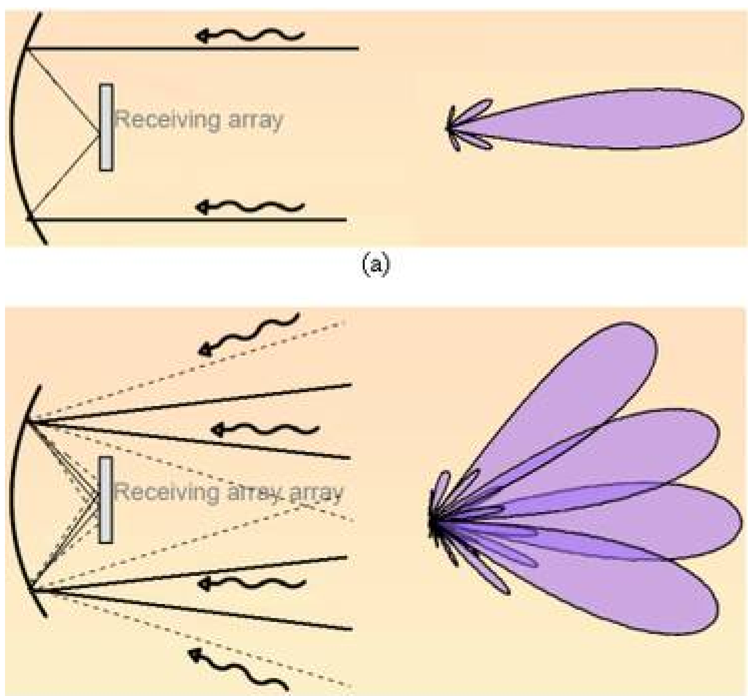
A typical distribution for the electric field amplitude in the focal plane is shown in Fig. 2(a). The general structure of the field has the shape of concentric rings, which can be either circular when the incidence of the wave coincides with the focal axis or modified rings when off-axis. Fig. 2(b) illustrates the idea how the continuous focal field distribution presented in Fig 2(a) can be reconstructed with 13 sample points (marked by digits 0-3) in a 5 X 5 rectangular grid antenna array. If antennas are placed at these points then the received signal can be reconstructed, this is called a focal plane arraw (FPA)



(a) (b)

Fig. 2 (a) The distribution of the field amplitude in the focal plane, and (b) the field synthesized with 13 sample points in a 5 X 5 Vivaldi element array

The antenna elements in the FPA shown in Fig. 2(b) are grouped by different colours and digits. To represent the concentric rings in Fig 2(a), each group of the elements in Fig. 2(b) marked by the same colour has the same amplitude. The amplitude of each of the 13 elements can be tuned independently. In a telescope, the waves picked up by the FPA will be amplified, phase shifted, and combined to form a beam. The typical radiation pattern of a telescope using such beam former is shown in Fig. 3(a). By adjusting the amplitude and phase of each element, the beam can be synthesized and steered electronically.



(b)

Fig. 3. (a) The radiation pattern of a one-beam telescope, and (b) the radiation pattern of a four-beam telescope by placing four FPAs in the focal plane.

It is possible to place a few such FPAs in the focus area to form multiple beams. The radiation pattern of a 4-beam telescope is illustrated in Fig. 3(b). However, if the FPAs are apart from each other, 52 antennas will be needed. The elements marked with the letter “a”, “b”, “c” or “d” as shown in Fig. 4(a) will be used for the 4 beams respectively. The colours of the letters correspond to the field amplitude as shown in Fig. 2(b). The central point of each FPA will be far off the focus point. These FPAs can be interconnected as shown in Fig. 4(b), where four beams are formed by using 24 antennas.

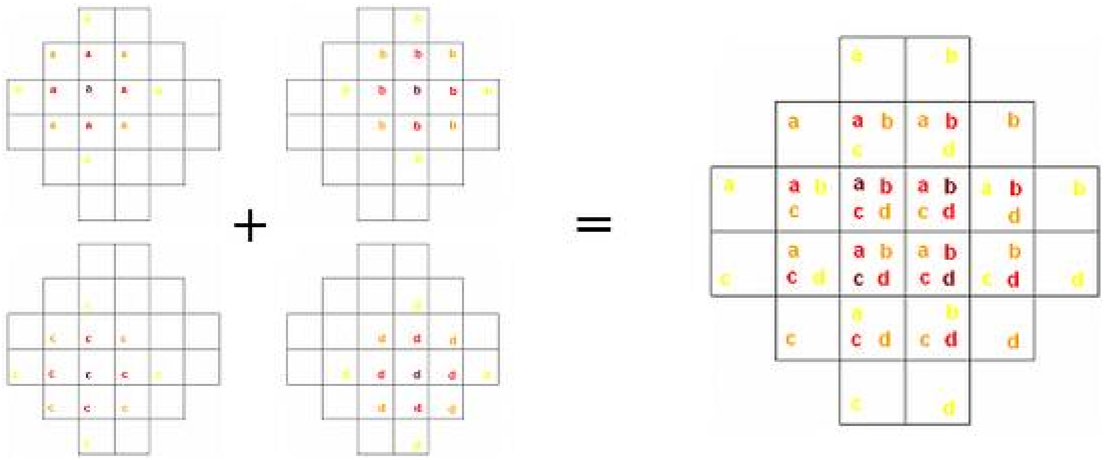


Fig 4. The logical configuration of four interconnected FPAs.

In this interconnected array, the central 4 antennas are used by all of the 4 beams. Therefore the wave picked up by these 4 antennas will be split into 4 outputs and fed into each of the beam former. Similarly, 8 antennas are used by 3 of the beams; the wave picked up by these antennas will be split into 3 outputs and fed into 3 of the beam formers. (In the realization, the waves received by these 8 antennas are also split into 4 outputs, with one output terminated to the ground as shown in Fig. 5 below.) The rest 12 antennas are only used by one of the beams and have one output without splitting. Filters are also used in each element to suppress interferences. The diagram of part of the system is shown in Fig 5. All of the 4 beams formed can be synthesized and steered electronically and independently.

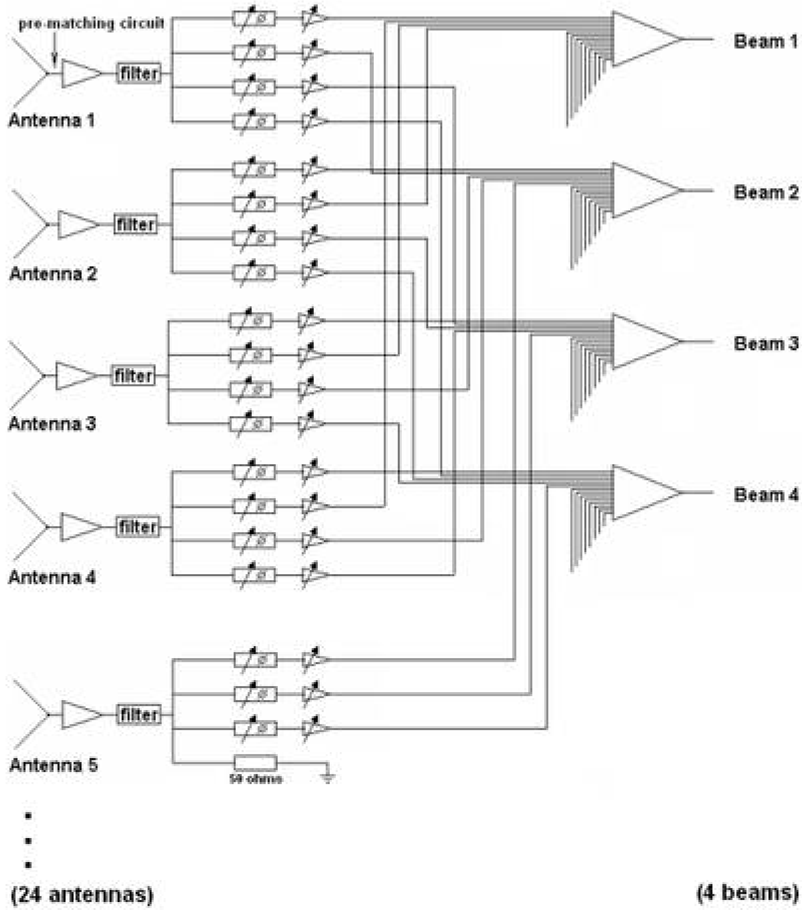


Fig. 5 The diagram of a four-beam former system. Antenna 1-4 are the central elements used by all of the beams. Antenna 5-12 (partly shown) are the elements surrounding the four central ones used by three beams. Antenna 13-24 (not shown) are the outside elements used by only one of the beams

As mentioned above, the front-end of the system works at a temperature below 20 K. It is therefore possible to employ high temperature superconducting (HTS) components without extra cooling device. The EDT Research group is responsible for the investigation of the potentials of the HTS for the antennas and RF circuitry in this project. One HTS application is the high performance filters required as shown in Fig. 5. More details on the HTS filter can be found in the "Superconducting Microwave Components For Radio Astronomy Applications" section.

Another interesting HTS application is a superconducting pre-matching circuit for the front-end LNAs. The matching circuit is between the antenna and the first LNA as shown in Fig. 5.The loss of this circuit plays a significant role in the system noise. By using virtually lossless HTS matching circuit, the noise performance of the system can be significantly improved. The layout of the HTS matching circuit is shown in Fig 6, which consists of a 1.2 nH inductor (the narrowest line) and a 58-ohm transmission line (the middle line). There is also a 50-ohm feed-in line (the widest line).

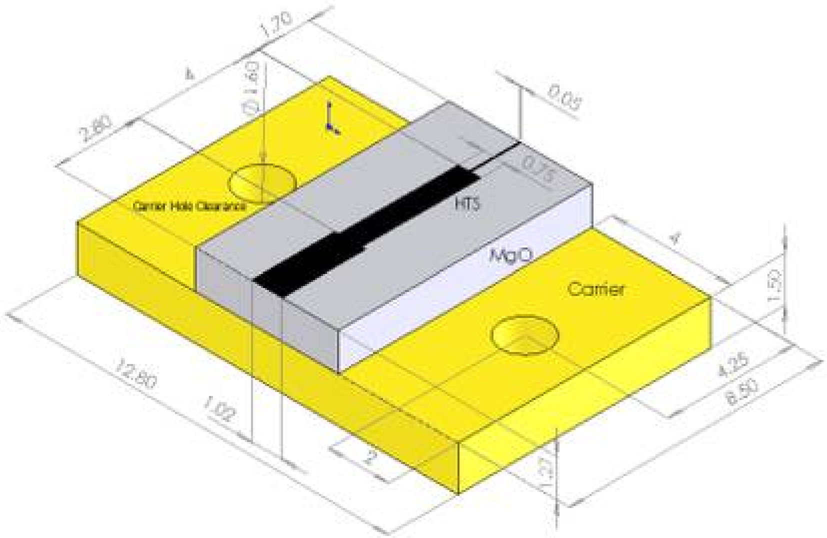


Fig. 6 Layout of the HTS matching circuit for the LNA.

The simulated noise performance of the LNA with the matching circuit is shown in Fig. 7. The red line indicates the minimum possible equivalent noise temperature (T_e) of the amplifier when it is perfectly matched for noise. The pink line, nearly overlapped with the red one, shows the simulated T_e when an HTS circuit is used for matching, and the blue line shows the simulated T_e when a copper circuit is used. It is clearly seen in Fig 7 that the T_e is about 8 Kelvin worse when the copper circuit is used, while the HTS circuit provides a near-perfect performance. This improvement is very desirable for astronomical applications.

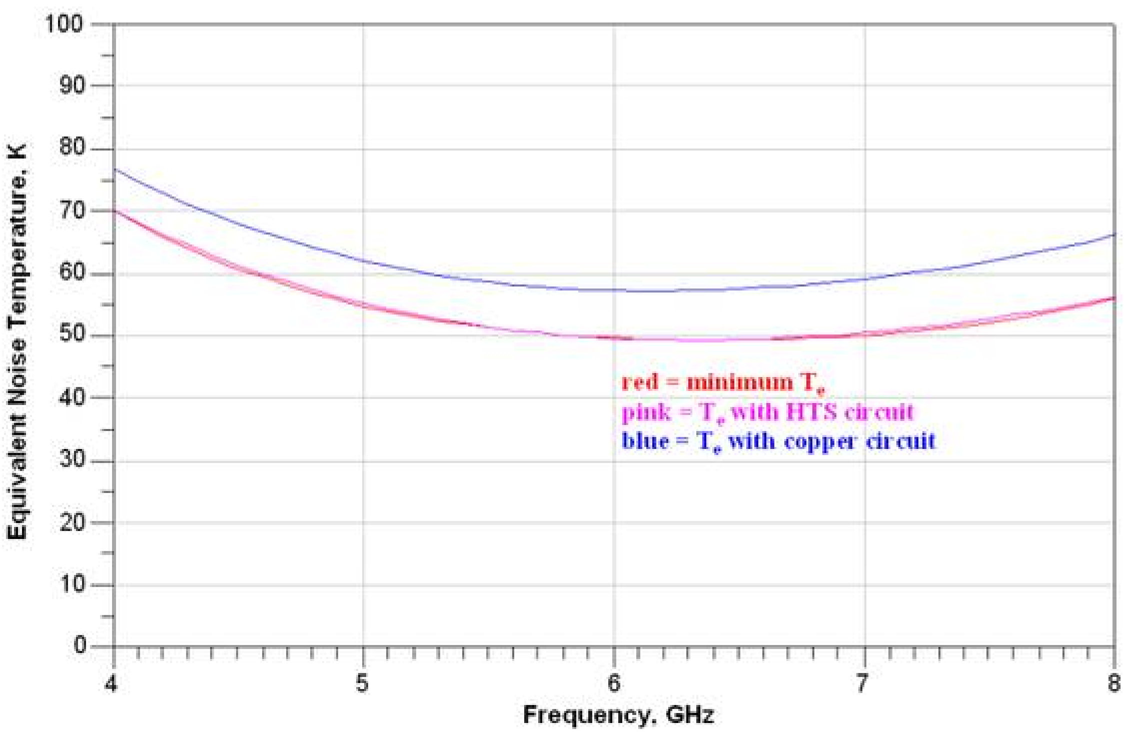


Fig. 7 The simulated equivalent noise temperature of the LNA with the matching circuit.

The web page of the Jodrell Bank Observatory, http://www.jb.man.ac.uk/tech/lovell/.