Development of Multibeam Heterodyne Receiver Frontends

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Abstract

This study aims to make essential breakthroughs in the techniques of constructing large-scale and compact superconducting multibeam receiver frontends. These techniques will lead to new instruments, which allow us (1) to realize frontends with pixel number N>100, an order of magnitude larger than the present ones, and (2) to fulfil small format (N~10) but very compact arrays (filling factor F>0.5 on focal plane) to be compatible to cartridge type receivers, and thus can be applied to interferometers like ALMA.

１． Background and Motivation

One of the main weaknesses of modern day radio telescopes such as Atacama Large Millimeter/submillimeter Array (ALMA, the world largest ground based telescope) is its small field of view (FOV), (21 arcsecs at 300 GHz). This is a SIGNIFICANT LIMITATION for surveys requiring large area mapping, such as galactic star formation regions, nearby galaxies, distant galaxy surveys, Magellanic Cloud studies, and solar observations. Another very important science case is to follow-up sources found in gravitational wave experiments, which requires an extremely wide field coverage. Wide FOV will also be important in terms of synergetic studies with future instruments such as TMT.

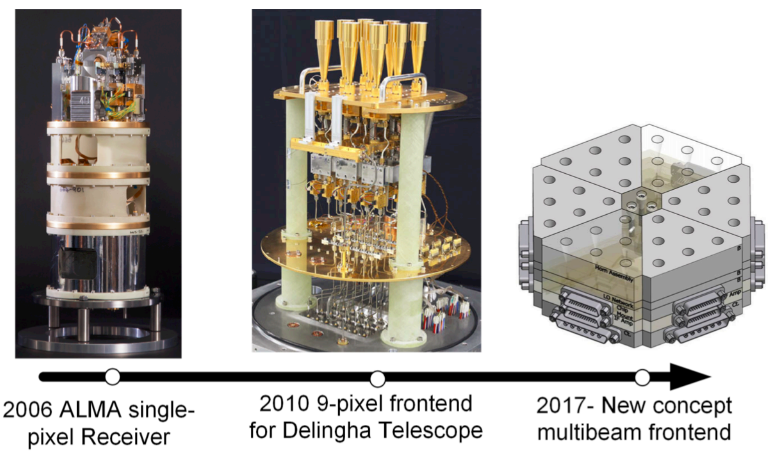

Fig. 1 The road map of this development

The attempts of extending the FOV of radio telescopes have continued for many decades. Right after the development of ALMA receivers, we started to develop receiver technologies in order to construct small-scale multipixel frontends that retain ultimate sensitivity. A 9-pixel Superconductor–Insulator–Superconductor (SIS) receiver frontend was successfully built and routinely operated [1]. However, we found out that a frontend with more pixels can hardly be reached without a REVOLUTIONARY CHANGE in the way of constructing multibeam frontends. In this study, we aim to explore a new concept and associated techniques in constructing large-scale multibeam frontends for next generation radio telescopes with wide FOVs.

2. Key Techniques

There is no established technique allowing either large number of pixels (N>100) or very compact multibeam frontends that would be compatible with ALMA receiver architecture. All existing multibeam receiver frontends were constructed by packing several structurally independent beams onto the focal plane, as shown in the upper panel of Fig. 2. Some attempts to integrate the frontends turned out to be not successful because manufacturing a built-in LO distribution waveguide network that stretches in 3D space is prohibitively difficult. Our method is based on an embedded quasi-2D LO distribution network supported by a monolithic SIS IC, as shown in the lower panel of Fig.2. DIFFERENT from all the other established or proposed SIS multibeam frontends, this approach is the ONLY ONE that will enable all of the following advanced technical features, namely dual polarization, sideband separation (2SB) and balanced mixing, in to a single multibeam frontend. The essential idea is to largely simplify the waveguide structures by transferring all the functions that are conventionally fulfilled by complicated metallic waveguide components to a planar SIS integrated circuit (IC), in particular orthomode transducers and 90 degree hybrid couplers. Although the SIS IC becomes much more complicated than before, we have confidence to handle it because of rich experience in developing of SIS mixers in NAOJ microfabrication laboratory.

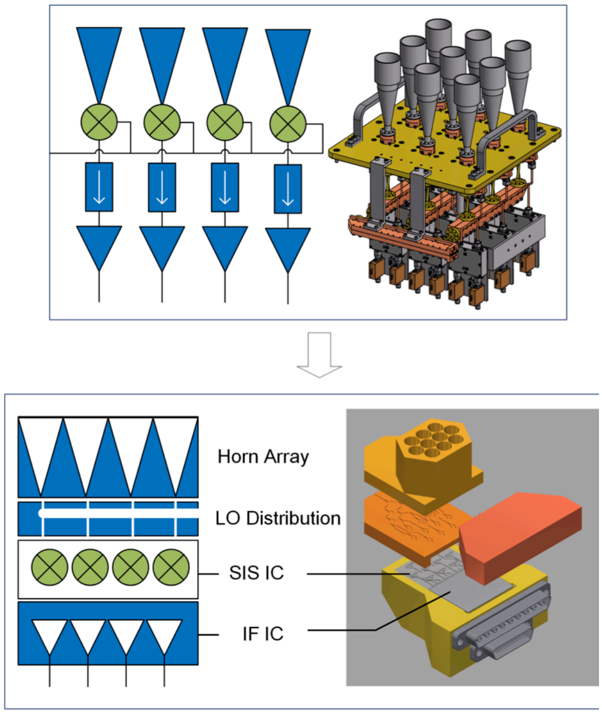

Fig. 2 (left) the conventional multibeam, and (right) the new concept of building a multibeam frontend.

In this talk, several key techniques resulting from the above idea, namely, planar OMT, integrated SIS circuits, as well as built-in LO waveguide network, will be explained in details to offer a complete overview of this study.

【Reference】

[1] Wenlei Shan, Ji Yang, Shengcai Shi, Qijun Yao, Yingxi Zuo, Zhenhui Lin, Shanhuai Chen, Xuguo Zhang, Wenying Duan, Aiqing Cao, Sheng Li, Zhenqiang Li, Jie Liu, Jiaqiang Zhong, "Development of Superconducting Spectroscopic Array Receiver: A Multibeam 2SB SIS Receiver for Millimeter-Wave Radio Astronomy," IEEE Transactions on Terahertz Science and Technology, vol.2 , issue 6, pp. 593-604, 2012.