K-band Phased Array Feed: Engineering Specifications

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Abstract

This document describes the engineering specifications for a K-band (18-27 GHz) Phased Array Feed

History

Version	Date	Notes
2.1	11 June 2016	Original Version (Richard Prestage)

Contents

1 Introduction

The intent of the project is to build a K-band (18-27 GHz) Phased Array Feed (KPAF) and associated IF system and beamformer electronics. This document provides the engineering specifications for such a system.

In the following, I propose we specify both targets (quantities that the system absolutely should achieve) and goals (more ambitious than the targets, and we may in the end not achieve them).

2 Rationale

The science case for KPAF is given in a separate document. Very briefly, the aims of KPAF – which may influence the specifications – are as follows, basically in this order:

- to enable wide area mapping of transitions of ammonia (NH_3) in our galaxy;
- to enable mapping of other molecular transitions which fall within the K-band window;
- to serve as a "multi-object spectrograph" for deep integrations of high redshift galaxies in a single field;
- to serve as a prototype / test-bed for a Ka-band, 34 GHz (TBD) PAF radar receiver;
- for other technology transfer processes.

The KPAF will explicitly *not* be required to support:

- point source observations;
- VLBI.

3 Basic Metrics

One of the key metrics for an array receiver is mapping speed. This is proportional to a number of system characteristics, and varies as:

$$M \propto N_{pols} \times N_{beams} \times \left(\frac{\eta_{ap}}{T_{sys}}\right)^2 \tag{1}$$

where M is the mapping speed, N_{pols} is the number of polarizations, N_{beams} is the number of formed beams, η_{ap} is the aperture efficiency, and T_{sys} is the system temperature. The system termperature at K-band can very widely due to water vapor (the H_2O resonance peak at 22.24 GHz) but chosing a typical value of $40K$ for the existing KFPA, the relevant quantities are:

$$M = 2 \times 7 \times \left(\frac{0.68}{40}\right)^2 \simeq 4 \times 10^{-3} \tag{2}$$

For KPAF I propose we set:

- Target: 5x improvement in mapping speed over the current KFPA
- Goal: 10x improvement in mapping speed over KFPA

Choosing numbers arbitrarily, consider values of $\eta_{ap} = 0.5$ and $T_{sys} = 50$. That would then require 100 dual-polarization or 200 single beams to meet the target, and 200 or 400 beams to meet the goal.

To be worthwhile then, it seems we will have to be able to form 100s of beams.

T_{sys} varies drastically at K-band due to variations in the atmosphere. How detailed an analysis do we need to do?

What other basic metrics are there? The only other fundamental one I can think of is beam quality.