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# The New JCMT Holographic Surface Mapping System - Implementation

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**Abstract.** The James Clerk Maxwell Telescope (JCMT) on the summit of Mauna Kea in Hawaii is a 15 meter telescope which operates in the sub-millimeter region of the spectrum (in practice from about 2 mm to 350 microns). Operation at such short wavelength requires the dish to have a surface accuracy of 20 microns RMS. The primary reflector surface consists of 276 panels each of which is positioned by 3 stepper motors. In order to ensure the highest possible surface accuracy we are embarking upon a project to improve the mapping of the surface.

The mapping of the primary reflector surface is achieved by "holographic" techniques. Currently a 94 GHz radiation source, located on a nearby Telescope (United Kingdom Infra-Red Telescope) is used to illuminate the JCMT surface. The orientation of the telescope is scanned in two coordinates to measure the beam pattern. From this it is possible to determine the path length of the radiation to, and hence the position of, each panel. A new instrument has been deployed in order to achieve greater accuracy and produce maps at a significantly faster rate. The instrument uses two main frequencies, 80 and 160 GHz, and is frequency agile around these frequencies to allow for the elimination of spurious signal paths.

## 1. Introduction

The James Clerk Maxwell telescope (JCMT) primary reflector is made up from 276 reflective panels. Each of these panels is attached to three stepper motors that allow the panels to be individually tilted in order to achieve the best shape for the highest antenna gain (Smith 1998).

To maintain and correct the parabolic shape of the primary reflector, a panel position detection system is employed. A 94 GHz radiation source located on the hill above (at the UKIRT) illuminates the JCMT, and its receiver detects this signal. By scanning the JCMT across the beam in a raster pattern whilst moving the secondary mirror up and down, the phase of the signal is recovered. This produces a whole-dish map of the vertical position and tilt of each panel (with 3 micron resolution and 12 micron repeatability).

## 2. Reasons for a New System

Whilst the current system provides the necessary information to maintain the surface of the JCMT, it suffers from several problems. One of the largest problems is that it takes about two hours to fully map the surface. Apart from the time aspect, this introduces errors given the fact that the temperature of the telescope structure changes over the period of the mapping. It is well known that temperature changes have a significant effect on the position of the panels. The only time when the temperature is stable over this sort of time period is the middle of the night, so to produce the best maps, normal observations have to be halted.

When moving panels, it is necessary to re-map the surface to check that the moves were sufficient and correct, and sometimes the panels need a further adjustment with a third map required. At ∼2 hours per map, this can consume an entire observing shift.

Other problems include spurious reflections from the protective Gortex membrane and other structures, as well as a growing maintenance burden from the aging system in place.

## 3. RxH3 Description

A new system described in the JCMT Holography Receiver RXH3 Preliminary Design Paper[1] has been constructed and was commissioned in December 2000. Still undergoing tests prior to calibration, its main features are: (1) a map of the surface can be produced in about 15 minutes, (2) measurement repeatability of 5 microns RMS, (3) dual frequency (80 & 160 GHz) system (using two frequencies provides a choice of either fast low resolution or slower high resolution mapping, and stepping around these frequencies provides the ability to solve and eliminate signals from spurious paths like reflections from the protective membrane), (4) dual signal system, main and reference beam, which produces both phase and amplitude of the signal, akin to a holographic measurement system and (5) a VME real-time computer data acquisition system for fast mapping and time stamping for accurate registration of the data.

## 4. RxH3 System Components Description

### 4.1. Components Located At UKIRT

*Real-Time Source Computer, Sx3* This is a PC with a PC-LabCard multi-IO and real-time clock card. This provides control over the PTS frequency synthesiser via a parallel interface. Frequency stepping patterns are received by

[1] `http://www.jach.hawaii.edu/JACdocs/JCMT/rxh3/d-1-1/d-1-1a.doc`

the PC via an RS232 interface, and when commanded, the PC runs the given pattern continuously at a 1 KHz rate. This is achieved by controlling the PTS synthesiser via a parallel interface.

*PTS Synthesiser* This digitally controlled frequency synthesiser can produce an output in the range 250 MHz to 350 MHz, and when coupled to the 80 GHz and 160 GHz signals generators produces controllable signals in the range 80.25 - 80.35 GHz and 160.5 - 160.75 GHz. This unit will step in frequency by 5 MHz, at a rate of 1 msec as per the pre-programmed frequency pattern. It will also blank the signal during each hop in order to synchronise the data acquisition system at JCMT, much like the blanking signal in a television signal.

*Source* This is a dual frequency system with 80 and 160 GHz channels orthogonally polarised by a wire grid.

### 4.2. Components Located at JCMT

*Optical Relay* This consists of two curved mirrors mounted on the backing structure of the JCMT. Their purpose is to fold the reference beam, which passes through a hole in the JCMT primary reflector, into the reference input of the RxH3 receiver.

*Receiver* The receiver consists of two channels, reference and signal, each with two mixers (80 GHz and 160 GHz) to produce a 300 MHz IF. These two IF signals are then passed through a dual channel correlation receiver and each channel produces a sine and cosine output. The signal blanking is also detected and used to generate a TTL sync pulse to drive the DAU (Data Acquisition Unit).

*DAU* The DAU is a VME-based 68060 computer with a Wind River's VxWorks operating system and applications coded in the Anglo-Australian Telescope's DRAMA C programming environment[2]). The DAU consists of: (1) a VME XYCOM XY566 16 channel programmable 12 bit A/D converter, (2) a VME XYCOM XY240 TTL I/O card and (3) a VME Bancom BC635VME RIGB card.

### 4.3. Software Components

The SYSCON (System Controller) DAU and DHS (Data Handling System) components have been written as DRAMA tasks. These tasks and the tcl Control Script communicate with each other using DRAMA messages.

*Control Script* The Control Script runs on a Unix workstation, coordinating all activity between systems and issuing STEP and CENTRE commands to the telescope. The concept of a map is understood only at this level, with other systems operating on a row by row basis. The script determines all required parameters for the requested map and generates it by iteratively issuing ROW commands to collect raster data.

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[2] `http://www.aao.gov.au/drama/html/dramaintro.html`

*SYSCON* This DRAMA task runs on a Unix workstation to control the DAU and DHS. In preparation to take data, SYSCON sends the Sx3 control PC a frequency pattern to be executed repeatedly and sends INITIALISE and CONFIGURE commands to the DAU and DHS DRAMA tasks. It instructs the DHS to open a FITS data file. Upon request, SYSCON will send a ROW command to the DAU and instruct the DHS to receive data, monitor the telescope position parameter, TSPOSN (time and position stamps), interpolate the collected TSPOSNs and write data to disk. When all rows are collected, SYSCON instructs DHS to close the data file.

*DAU* This VME software consists of a VxWorks task and a DRAMA task that enables the A/D card to acquire data from the RxH3 receiver analogue channels. The frequency band is selected, and the Rx state is monitored by the TTL I/O card. Up to 20000 samples can be acquired by the A/D for each row at a rate of 1 K samples per second. Each time the data are sampled, the time card is read, and the time-stamp, TTL status byte and data are stored. Data acquisition is normally synchronised to both the telescope "On Source" (start of row) pulse and the digitisation SYNC pulses generated by the Rx. Once ROW data are collected, the data set is sent to the DHS task as a DRAMA bulk message.

*DHS* This DRAMA task accepts bulk data messages from the DAU, receives a stream of telescope positions, generates interpolated telescope positions and writes the data to disk.

### 4.4. Conclusion

RxH3 will quite literally revolutionise the maintenance of the dish as well as achieve significant improvements in surface accuracy.

The ability to map the surface in 15 to 30 minutes will permit the rapid correction of aberrant panels. It will be possible to make many adjustment iterations within just a few hours, and errors introduced by thermal drift in the current system will be minimal.

A surface accuracy of 5 microns RMS will be a significant improvement over that currently achievable and will significantly improve telescope efficiency.

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## References

Smith, I. 1998, Proc. SPIE, 3351, 190