LuftBlick report 2018001

ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study

Final tracker design and performance document

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1 Introduction

This report is deliverable D2 of CCN#1 to ESA's Pandonia project. In the first deliverable D1 of WP1, the design and performance of a first tracker prototype after a testing phase in Innsbruck was described. While the test results were very good in most aspects, this first prototype still had one major issue: the hardware costs already exceeded 5000 Euro, which brings the total costs of the tracker up to about 10000 Euro per piece. For this reason, in a meeting with ESA in October 2017, LuftBlick offered to ESA, that it will work together with SciGlob on a modified new tracker version, of which the hardware costs will be below 3000 Euro. This second prototype is described here.

Section 2 of this report describes the different elements of this second prototype and gives tracker specifications. Section 3 provides an overview about the tracker performance after the final testing phase and shows up advantages over the current tracker and the 1st prototype.

2 Tracker construction

Figure 1 shows the tracker prototype with (left panel) and without (right panel) sealed enclosure. Its main parts are:

- Stepper motors
- Gears and motion mechanism
- Controller and communication interface
- Frame
- Enclosure

In the following sections each part is described.

Figure 1: Tracker prototype without sealed enclosure (left panel) and with enclosure and the Pandora head sensor (right panel).

2.1 Stepper Motors

The tracker includes two stepper motors AZM46AK-HP9 from Oriental motors, one for the zenith and one for the azimuth movement (see figure 2). This is a standard NEMA (National Electrical Manufacturers Association) size 17 motor with an absolute encoder attached directly to the motor shaft.

Figure 2: AZM46AK-HP9 motor

2.2 Gears and motion mechanism

The tracker has gears from Silverthin Bearing Group. The gears handle two different types of motion:

- Smooth, short, low speed motion for the sun scans in order to avoid vibration during this measurement mode.
- Faster, long motion for the sky profiling and other applications.

A flanged slewing ring turntable bearing is used, which has excellent durability and flexibility and is compatible with the stepper motor. In order to reduce the “backlash”, i.e. the clearance between the slewing ring gear and mating pinion, the center distance between the slewing ring and pinion is adjustable giving us more flexibility whenever a motor replacement or repair is necessary. The gear reduction mechanism is built by Oriental motion (figure 3). It employs high precision gears with a cross roller bearing. This adjustment mechanism is highly efficient in eliminating backlash. It has a repetitive positioning accuracy of ±15 sec (±0.004°) and a loss of motion of 2 arc minutes.

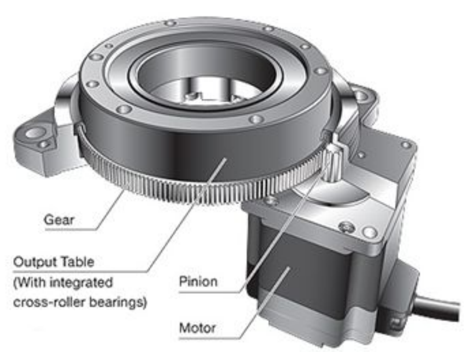

Figure 3: Gear reduction mechanism

2.3 Controller and communication interface

The tracker uses a low power off-the-shelf microcontroller for the tracker communication and control interface, Model RCM 4100 from RabbitCore (figure 4). This controller has enough analog and digital input and output signals to monitor the motors, gears, external sensors and temperatures, and includes an auxiliary Input/Output feature for reducing the processor bus loading.

Another advantage of this controller is that it allows easy integration of peripheral technologies such as GPS (Global Positioning System), cellular modems, etc., in case we want to include such elements in a future modification of the sun tracker.

Data and commands are transferred from the microcontroller's interface board to the built-in motor controller through a high speed RS-488 communication port. The communication protocol allows for real time communication with the motors giving the user the possibility to interrupt an ongoing motion and update the location and speed whenever it is necessary.

Figure 4: RabbitCore RCM4100 controller
Up to 40 GPIO (General Purpose Input/Output)
59 MHz – 512K Flash
256K / 512K Data SRAM (Static random access memory)
8 channels 12-bit A/D converter
Up to 6 CMOS-compatible serial ports

2.4 Frame

The tracker frame (figure 1) is made out of high clear anodized Aluminum while the shaft, bearings and collars are made of high grade stainless steel.

2.5 Sealed enclosure

A water tight aluminum enclosure has been developed for the protection of the motors and associated mechanisms as well as the motors' electronics (see figure 1). The enclosure is equipped with a military grade electrical connector for power and signal transmission. The enclosure of the 2nd prototype has a cylindrical shape whereas it waaas

2.6 Final tracker specifications

The final tracker specifications are listed below.

- Total hardware costs is about 3000 EUR per tracker.
- Basic step resolution of 0.04°, but the motor can be driven under micro-stepping mode, where we reach a resolution of 0.01° or better if needed.
- Smooth movements due to slow acceleration and deceleration.
- Stepper motor speed programmable from 0 up to 444 rounds per min.
- Harmonic planetary gear with a 9:1 gear ratio.
- Rotation range for both motors >360° for better water draining and also for scientific applications looking below the horizon.
- Absolute mechanical encoder, meaning cable winding is prevented e.g. after a power outage.
- Permissible load: 15 kg, can be equipped with electromagnetic breaks if load is higher.
- Monitored parameters
    - Temperature of motor and motor driver
    - Optional: Enclosure temperature, humidity and pressure.
- Programmable parameters:
    - Speed
    - Acceleration
    - Step resolution
    - Home position
    - Rotation range.
- Low vibration even at low speed thanks to the microstep drive system. With the smooth drive function of the stepper motor, resolution can be improved without mechanical elements such as a speed reduction mechanism. As a result, speed fluctuation is minimal even at low speeds, leading to improved stability.
- Tight inner construction for long term, heavy duty, outdoor use (>2 years) without maintenance.
- Analog interface with multiple analog inputs which provides the possibility to monitor and control the temperature of the electronics and the motors.
- Digital interface with multiple I/O signals that could be used for communicating with a GPS.
- Dimensions of tracker housing: 30cm height
- Dimensions of the system, i.e. tracker with head sensor mounted:
    - Height: 48cm
    - Width: 50cm
    - Depth: 53cm (is basically the head sensor)

3 Tracker performance evaluation

The 2nd tracker prototype has been tested in Maryland, USA.
Improvements in the operation of this prototype compared to the old tracker have been monitored and are listed in the following section. Then, the improvements towards the 1st prototype are summarized.

3.1 Improvements compared to old Pandora tracker

- The tracker reset is much faster (about 5 seconds versus about 100 seconds total reset time).
- There is less setback in the azimuth and zenith direction. This is important when it is windy or if an operator wants to install the Pandora on a ship or on an aeroplane, since the head sensor inside the new tracker does not vibrate that much.
- Smoother movements due to slow acceleration and deceleration.
- It can carry more weight. This has two advantages:
    - It does not wear out as fast as the old tracker did. For example, after only 6 months of operation, the old Pandora 110 tracker developed a margin of >2° because it was not designed for the weight of this head sensor.
    - With regard to the field calibration tool, it is important that the tracker can carry more weight. We came to the conclusion, that we will use a field calibration tool without an optical fiber because the spectral measurements are not repetitive due to the fiber instability. Instead, we will put the lamp directly onto the head sensor which would mean too much weight for the old tracker but not for the new one.
- From a practical point of view, the head sensor is easier to attach on the new tracker. This can be very helpful when the access to the instrument is complicated like it is often the case in remote stations.
- Due to the higher motion range, the head sensor can look into nadir position. This means, that the water can easily drain, which enhances the data quality after rainfall.
- With the absolute mechanical encoder, the software always knows the absolute position of the tracker and cable windings, e.g. after a power outage can be prevented.

3.2 Improvements towards the 1st tracker prototype from D1

These results are based on a first 10 days test period at SciGlob in Maryland, USA. The tracker will be sent to LuftBlick in March 2018 for further evaluation.

- After improving the sealing of the tracker housing, no traces of rust or moisture in the interior of the tracker after the final testing phase did occur so far. In the 1st tracker prototype a rust film was visible after testing it for one month in Innsbruck.
- In the initial tracker prototype version, the lockers were not handy and they have been another reason (beside the bad sealing) for the moisture ingress. This has been improved and the tracker has a cap which is fixed with screws.

- One of the plastic mounts for the head sensor was broken when the 1st tracker was delivered to Innsbruck. This is the reason why the mounts are made out of aluminum for the final tracker version.

3.3 Additional features of the new tracker system

- The new tracker prototype can perform so-called “quick sun searches” (routine FQ). This means, the Pandora locates the sun before every direct sun measurement and not only every 30min like in a typical schedule operation. This improves the pointing accuracy for the subsequent direct sun measurement.
- There is a magnetic encoder in the tracker prototype. The advantage of the magnetic encoder is that it could be used to detect situations, where some steps of the stepper motor have been lost, which happens in the current tracker system. Currently the position output of the magnetic encoder is only programmed in the low level communication code, but not used in the high level pointing algorithm. The reason is that we have to find the exact relationship between the step number and the readings of the encoder first.