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FEM application to improve the performance of the LUT for the SRT main reflector active surface

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SRT
Sardinia Radio Telescope

Introduction

The Sardinia Radio Telescope (SRT) is a fully steerable antenna with a 64 metre diameter main reflector. It is designed to operate in the frequency range from 0.3 GHz to 116 GHz. At such a wavelengths, the radio telescope performance requirements, in terms of both pointing accuracy and main reflector surface accuracy, are very strict.
Therefore, to ensure that the surface accuracy requirement is always met, the SRT is equipped with an active surface (Fig. 1), composed by 1008 panels which can be moved by means 1116 actuators in order to minimise the deflections produced by gravitational and thermal loads acting on the mirrors and on the Back Up Structure (BUS).

Fig .1 - Sardinia Radio Telescope Main Reflector (M1). The active surface (AS) allow to modify the shape of the mirror to maintain the profile always close to the ideal one.

Among the environmental influences, the gravity produces the greatest structural effects, which vary as the antenna configuration changes in terms of the elevation angle.
For this reason, the main reflector shape is automatically modified during the antenna operations, by means a Look Up Table (LUT) which contains the actuators elongation at several specific elevation angles.
The reflector shape correction for a set of exact antenna elevations, [15° - 30° - 45° - 60° - 75° - 90°], has been estimated through photogrammetric survey performed during the antenna assembly, once the panels of the mirror were aligned to minimise the deflections al 45 degrees elevation angle.
The corrections for the intermediate elevations to those predefined by the LUT, are analytically estimated using linear interpolations. The interpolant function parameters are estimated for each actuator and for every LUT elevation interval.
The purpose of this study is to evaluate, using a modelling approach based on the Finite Element Method (FEM), the shape errors at the antenna elevations among those considered in the LUT, caused by the use of the linear interpolation. In addition, the aim is to find an improved solution to reduce the surface RMS compared to the ideal shape of the primary mirror, at each angle of elevation in which the SRT operates.

Comparison between the SRT effective structure and its FE model

The ANSYS Finite Element (FE) model of the antenna is composed of 93,635 elements and 92,788 nodes (Fig .2).
The SRT FE model has been updated to reduce the differences between the simulated structural behaviour and the effective one.

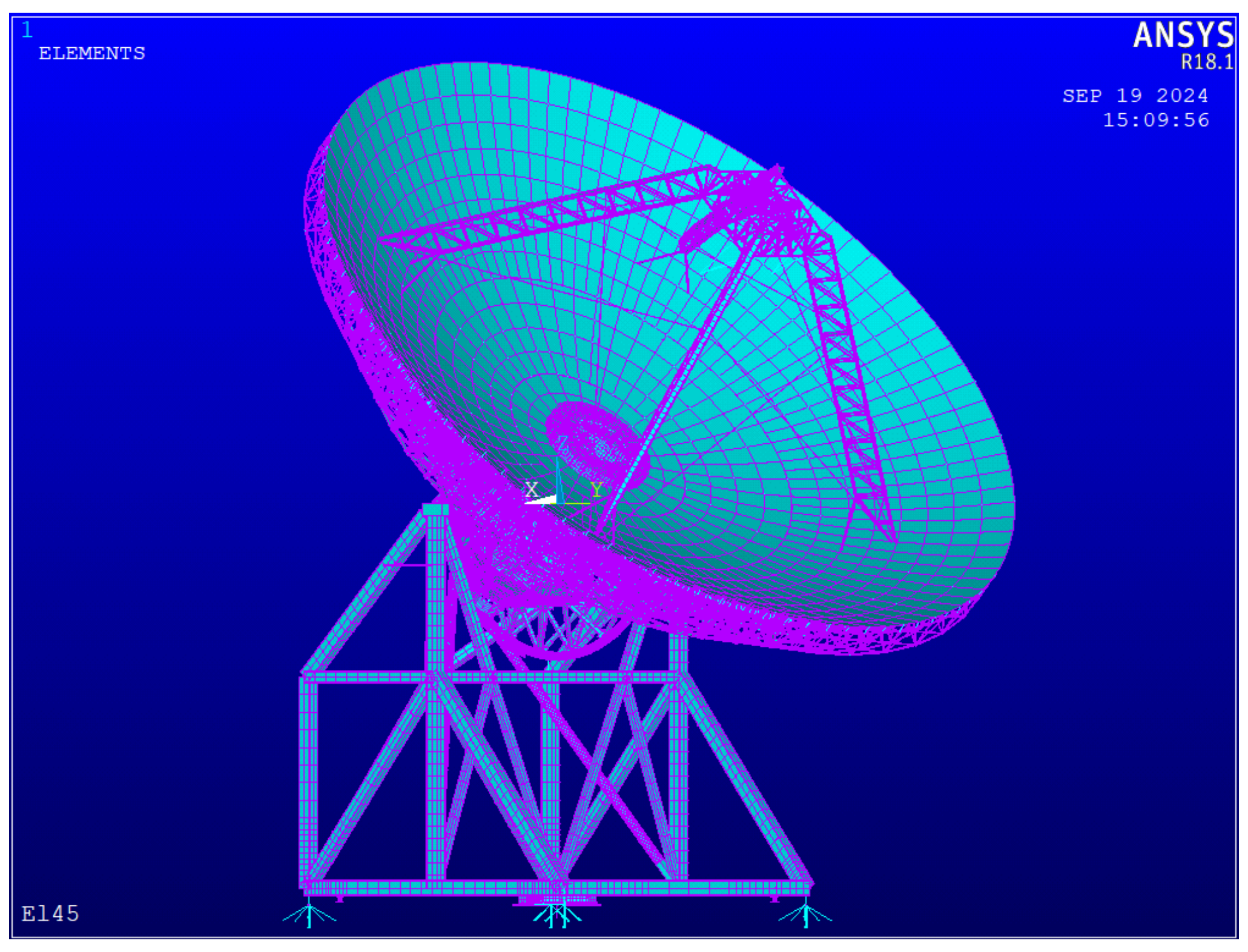

Fig. 2 - SRT Finite Element Model, represented in the configuration with the elevation angle equal to 45°.

In this way, as shown in Figs. 3-4, it has been possible to reach a good match among the gravitational effects measured by means phogrammetric surveys and those simulated.

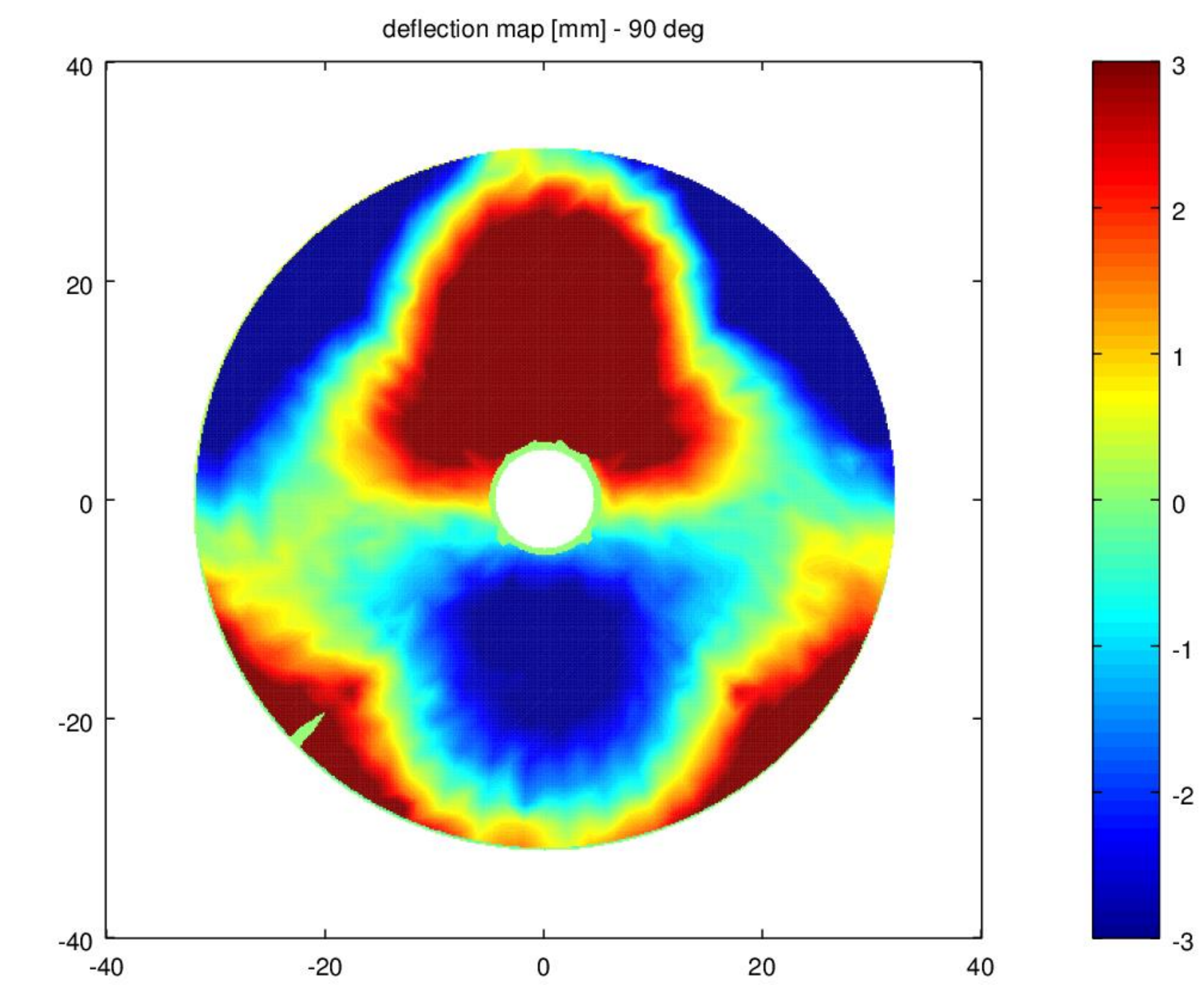

Fig. 3 - Deflections on M1 with AS off, expressed in millimeters, measured through photogrammetric surveys; the surface displacements has been generated by the gravitational load at 90° elevation angle.

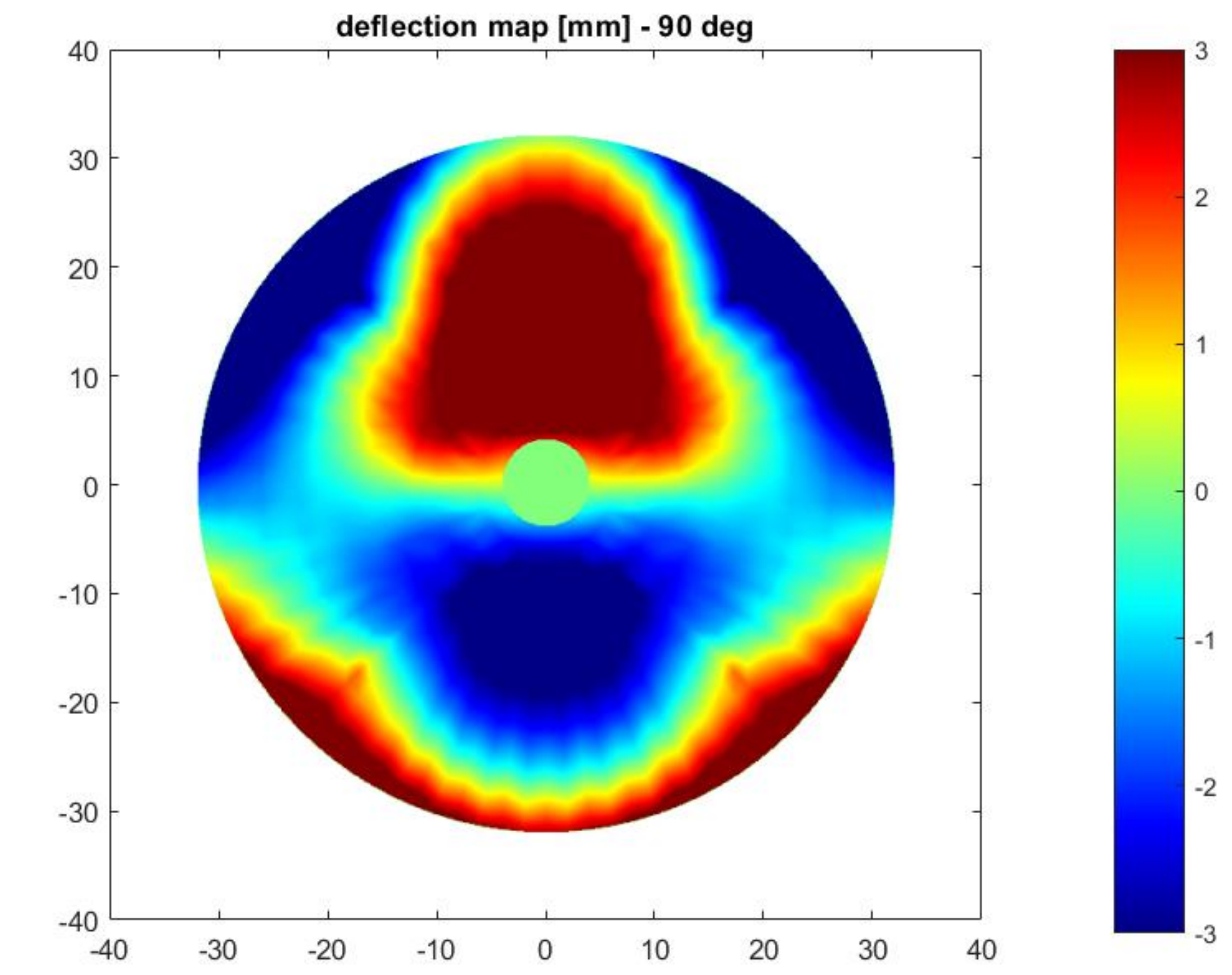

Fig. 4 - Deflections on M1 with AS off, expressed in millimeters, simulated by the FE model of the SRT; the surface displacements has been generated by the gravitational load at 90° elevation angle.

Linear interpolation performance

For the elevations neglected by the photogrammetry, a linear interpolation is adopted to calculate the elongation of each AS actuator.
To evaluate the performance ensured applying the linear interpolation, the potential of the modelling approach has been exploit, which give the opportunity to investigate large quantities of stress conditions with low computational resources.
Thus, the gravitational load condition have been simulated at several antenna elevation angles in order to compare the results with the corrections resulting from the LUT linear interpolation. In this way, it was possible to analyze the residual surface errors distribution over the main mirror. Fig. 5 show the residuals error maps at high and low angle in the elevation range of the SRT.

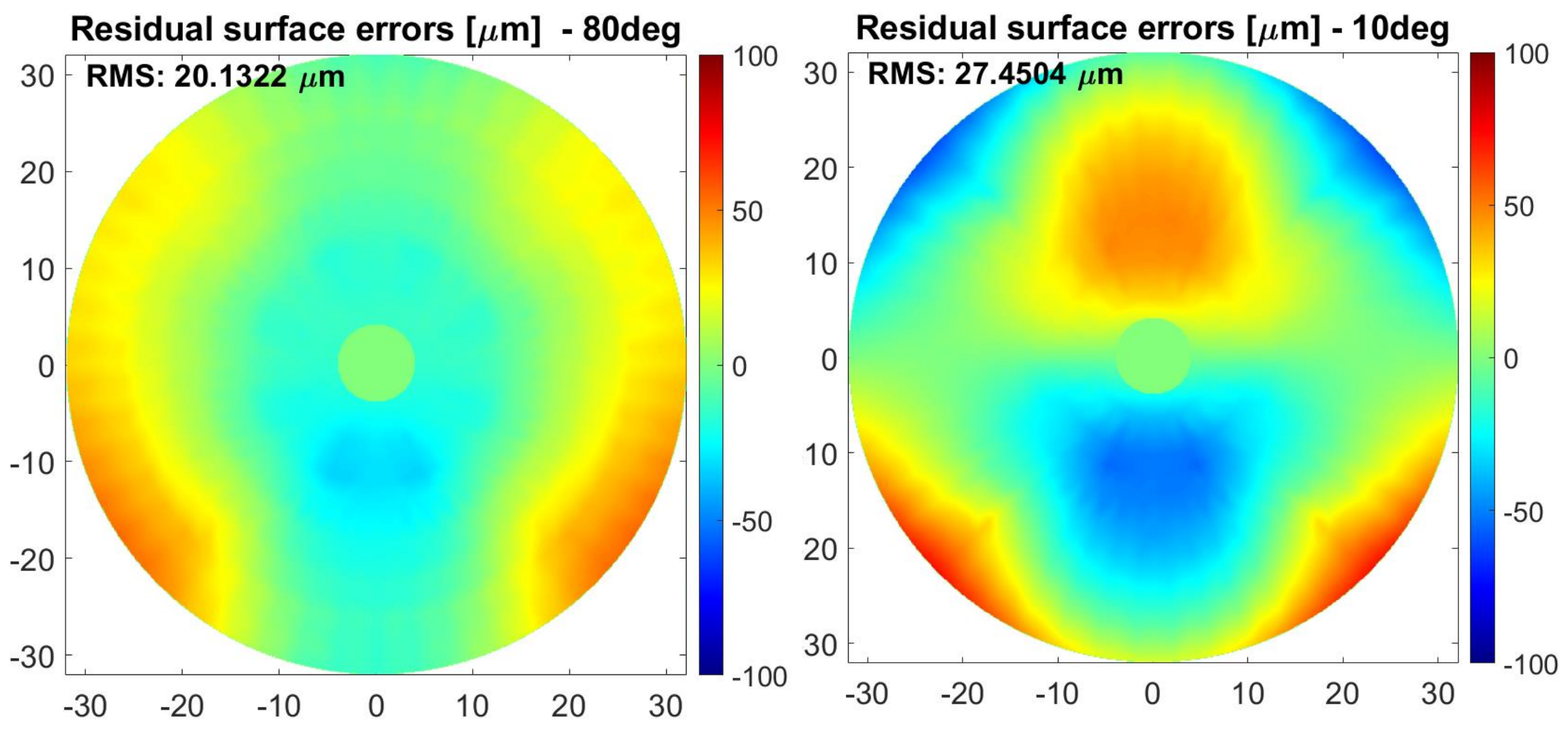

Fig. 5 – Simulated residual surface errors after the correction performed using a linear interpolation of the LUT at high, medium and low angles in the elevation range of the SRT.

Analysis show a diffuse surface errors resulting in optical aberrations. The global residual RMS vary with the change in elevation angle: at the lower angles it reaches about 30 microns while at the upper end of the range it is just over 20 microns.
The behavior is due to the elongation trend of the actuators resulting from the linear interpolation, compared with the primary mirror deflections throughout the elevation range in which the SRT operates (Fig. 6).

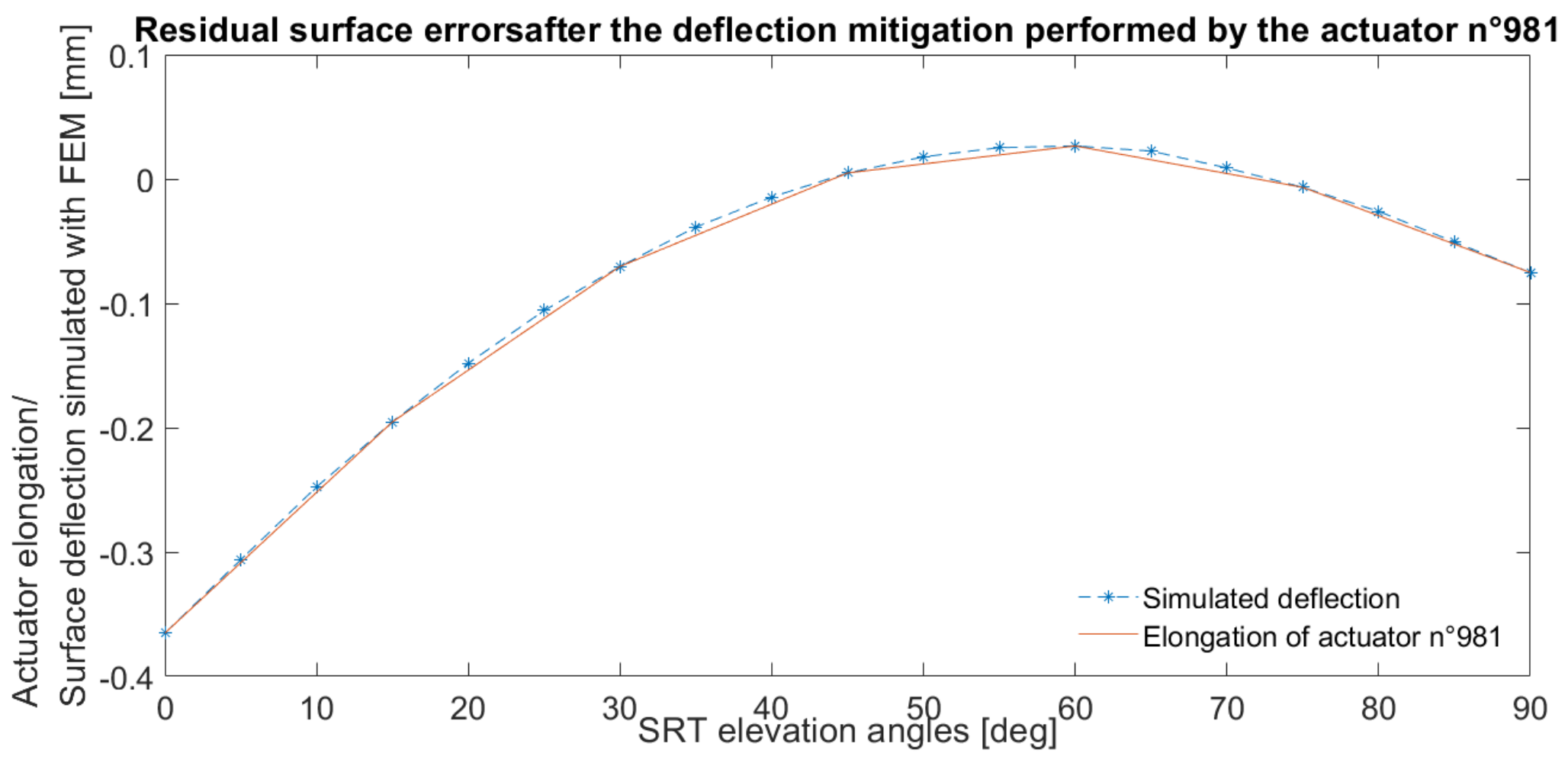

Fig. 6 - Comparison from the elongations commanded to the actuator n°981 and the displacement orthogonal to the M1 surface in the same point.

Polynomial interpolation approach

As already described, the LUT provides the elongations according to 15° amplitude intervals, with five distinct intervals in total.
Starting from this assumption, constraints can be imposed on the interpolating functions of each actuator, i.e. the equality of the curve value to the results provided by the FEM.
Since each interval of the LUT has an amplitude of 15°, elongations every 5 degrees were used as a constraint condition. Thus, in each interval of the LUT, it was possible to force the interpolating function to pass through four specific points. Since the degree of the polynomial passing through *n* points is *n-1*, third degree polynomial fulfils the requirements in this case of study.
Then, it was possible to model the residual surface errors after the implementation of the 3rd-degree polynomial interpolation of the LUT, at several angles in the elevation range of the SRT. Fig. 7 highlights a reduction in residual surface RMS of two orders of magnitude respect to the linear interpolation.

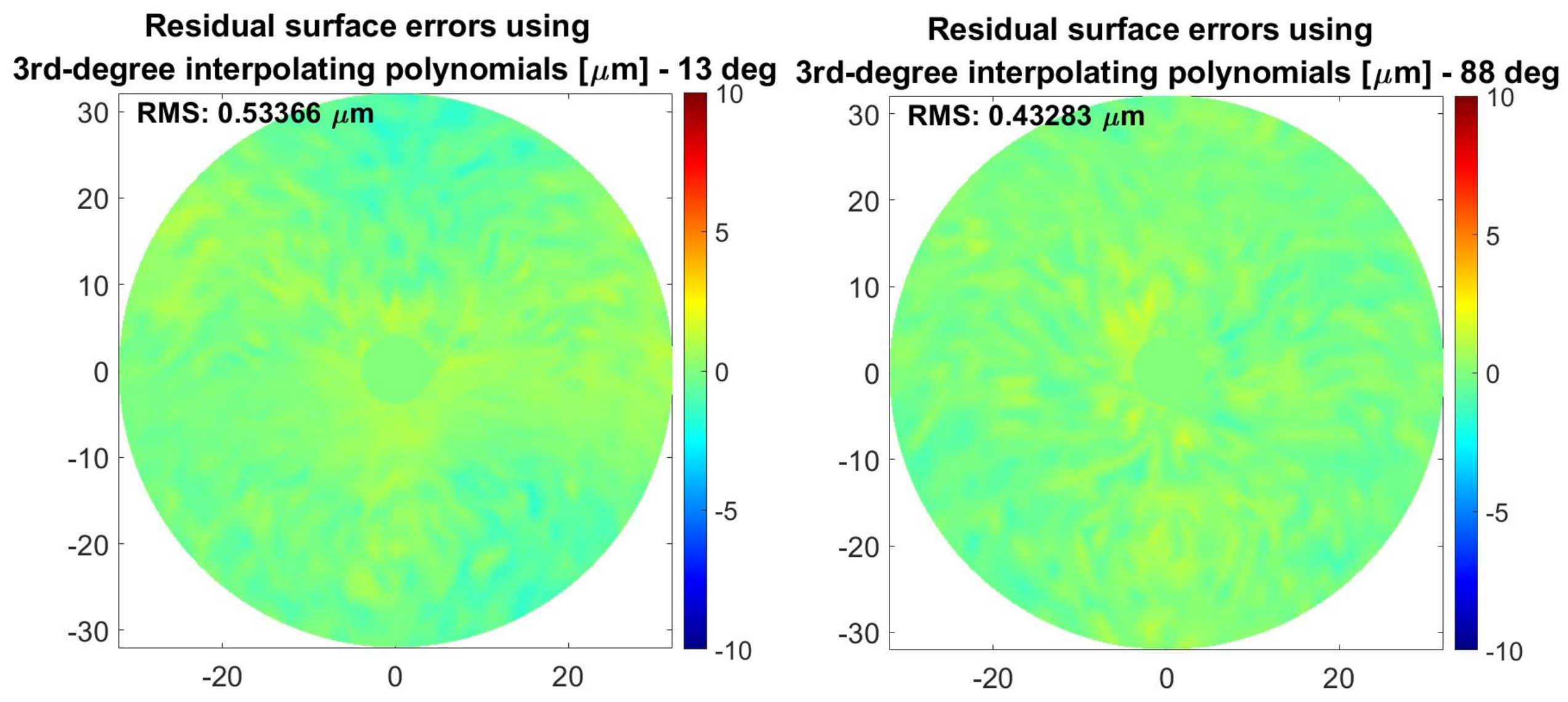

Fig .7 - Simulated residual surface errors after the correction performed using a 3rd-degree polynomial interpolation of the LUT .

Conclusions

Through the proposed study based on modelling approach, it was possible to evaluate the error committed by using linear interpolation for elevations that differ from those specified in the LUT.
The results show that the residual surface error varies with the elevation angle of the antenna and the residual RMS can reach a value of approximately 30 microns at the lower elevations. Although the magnitude of residual surface errors is small compared to the gravitational effects on the SRT primary mirror, their compensation could make a difference especially when observing at the highest operating frequencies (116 GHz), where it must be ensured that the surface error is less than 160 microns.
For this reason, it has been investigated the possibility of improving the LUT utilization strategy by changing the degree of the interpolating function.
A third-degree polynomial function has been chosen, which made it possible to reduce the residual surface error and obtain a maximum residual RMS value of approximately 1 micron.
Given the good match between simulated and effective structural behavior, the plan is to use in the field the interpolant polynomial coefficients estimated through the FE analysis for each active surface actuator. Through the metrological instruments installed on the SRT, including an Absolute tracker ATS600, it will be possible to evaluate the actual goodness of the results obtained by applying the described approach.

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