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A Low-cost High-frequency DIMM Platform for the Hobby-Eberly Telescope

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ABSTRACT

A tower and access platform were fabricated and erected for the Hobby-Eberly Telescope (HET) Differential Image Motion Monitor (DIMM). The 5 meter high tower exhibits a fundamental frequency of 43 Hz. The cost of the tower system, including access platform and enclosure was $12K US. The enclosure includes a unique application of an off-the-shelf truck accessory that serves as a shutter. The enclosure is ventilated, and incorporates a windshield to reduce vibrations that have proven problematic in the Meade Telescopes used for the DIMM system.

Keywords: Hobby-Eberly Telescope, HET, site seeing, DIMM, shutter, tower, enclosure.

1. INTRODUCTION

Reliable DIMM measurements have proven to be a critical bench mark in characterizing the performance of the HET. Such measurements were hampered by the need to set up portable DIMM telescopes on a nightly basis, by HET operators. A comprehensive investigation of previous DIMM platform designs used at observatories through out the world enabled the HET to learn many lessons and design a platform and enclosure that has proven to maximize the stability of the DIMM telescope and minimize the seeing impact of its protective enclosure.

The site chosen for the DIMM platform is a little over 100 meters southwest of the HET enclosure (Figure 1). This places the DIMM telescope on, or near, the leading edge of prevailing winds flowing over Mt. Fowlkes (elevation 2030 meters). The elevation of the DIMM telescope was set at 5 meters, about the same relative elevation of the center of the HET primary mirror above the local terrain. The elevation was set, based upon the desire to measure the sight seeing of the HET primary mirror, rather than the seeing above the boundary layer. Measurements by Barker and John McGraw show that the boundary layer is at least 5-7 meters in elevation above local terrain.

2. DESIGN & ANALYSIS

The key design goals for the HET DIMM platform were; 1) platform stability, 2) minimal seeing impact (primarily thermal heating), 3) reduced wind-shake in telescope drive and mount mechanism, 4) weather protection, 5) automated operation, 6) maintenance access, and 7) $25k maximum budget. The completed HET DIMM facility is shown in Figure 2.

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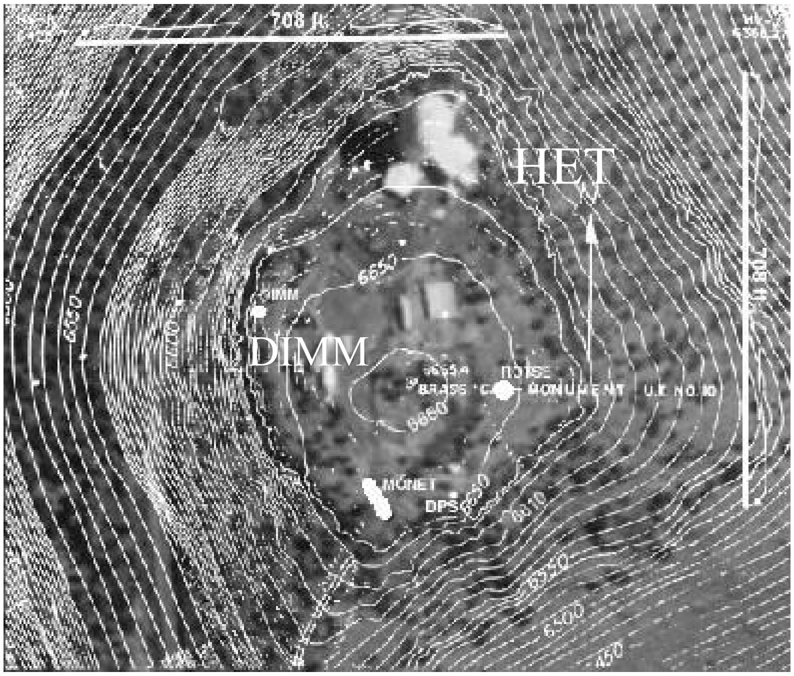

Figure 1: Location of HET DIMM Relative to HET.

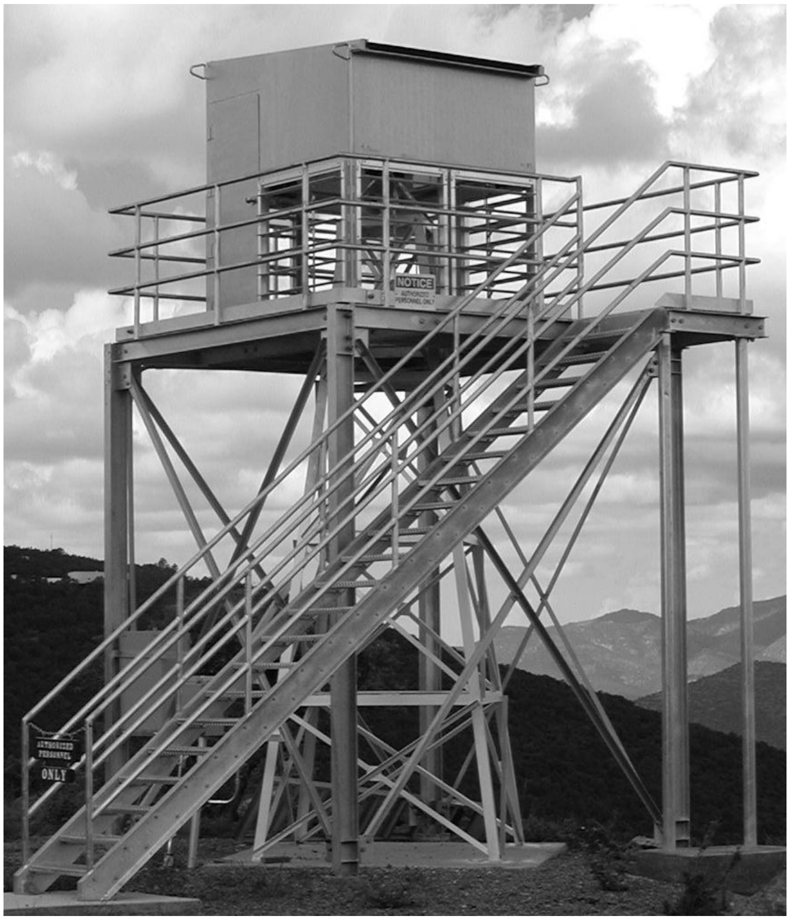

Figure 2: The HET DIMM facility with the louvers and roof open.

2.1 TOWER DESIGN

The original paper by Sarazin and Roddier[1], on the principal of the Differential Image Motion Monitor argued against the usual requirement for a stable telescope mounting platform. In practice, however, because of the limitations in imaging at high rates, DIMM performance has been shown to greatly improve as the platform stability increases, because the shake induced by winds may move both images outside the acquisition window on the CCD camera. Investigation of previous designs such as Gemini South's tower within a tower Figure 3, revealed problems with DIMM performance as winds increased. The Serrurier type truss used by ESO (Figure 4) at a number of locations has subsequently been analyzed for the effectiveness of "guy-wires", Figure 5 to provide increased stiffness. HET's experience with the Meade telescope mount, used for our DIMM, mounted on a portable tripod have demonstrated consistently better sampling of the seeing in lower wind conditions.

Figure 3: Gemini South's DIMM tower (right) is shielded from wind by an outer tower.

Problems with the tower within a tower design, (outer tower serving as a wind shield for the inner tower), are familiar to HET also. The 90 ft tall alignment tower for the primary mirror is coupled sufficiently through the tower foundation to cause significant energy transfer in even mild winds, necessitating the use of "guy-wires" to stiffen the outer tower.

While the principle of the Serrier-type truss is attractive in theory, since any displacement due to vibration is not angular, there are problems in implementation. First, since the top and bottom of the structure must be approximately the same size, it results in a structure with unnecessary mass at the top, or one with an impractically small base. Also, if the structure aspect ratio is sized properly for good stiffness then it is difficult to provide a stiff interface to a small telescope base, since the top of the structure will be too large. (Figure 6). In addition, there will always be a finite angular component in the displacement of the top of the truss due to the failure of the nodes to meet the theoretical requirement for structural joints which rotate without friction yet have zero "play" in all other directions of motion.

If, however, the structure can be made as light as possible as it increases in height, and be very stiff, the resonant frequency will be so much higher than the excitation frequency of the wind (about 0.2 Hz)[2] impacting the structure, that the angular component of displacement will be very small. The need to

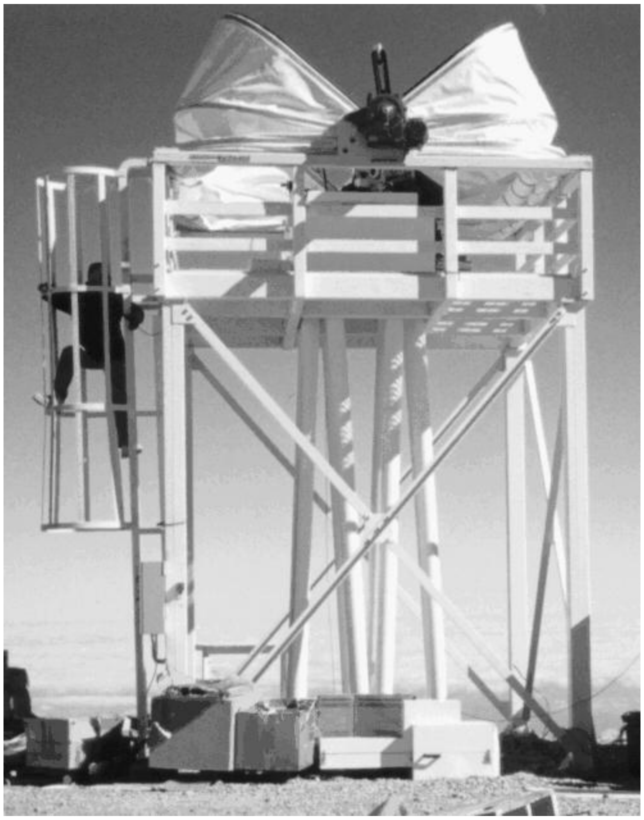

Figure 4: The ESO DIMM tower (Surrier-type truss) and platform.

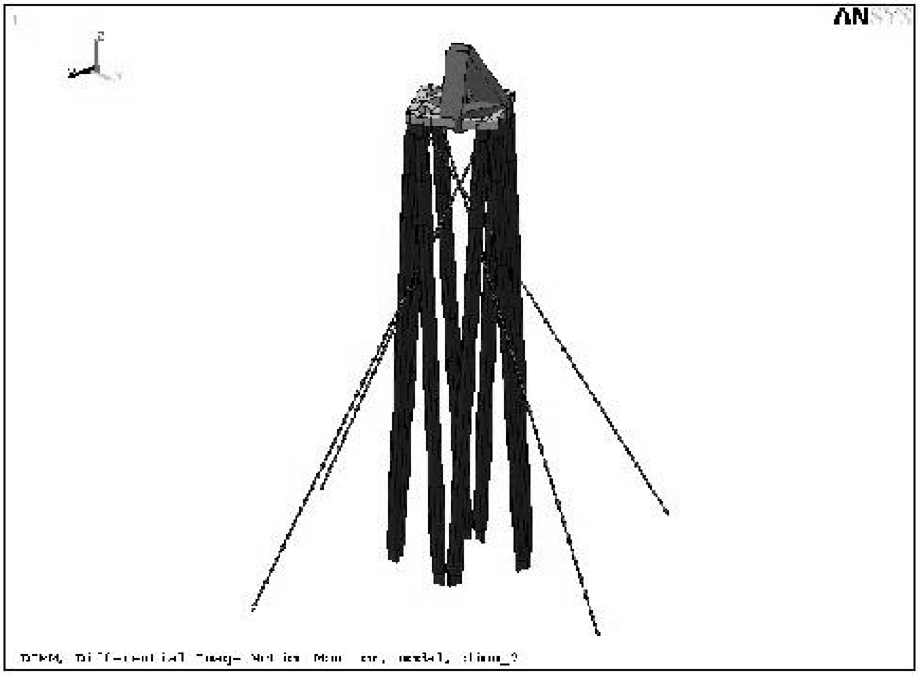

Figure 5: Finite Element Model[2] of ESO's Surrier-type truss stiffened with guy wires increasing fundamental frequency from 7.5 Hz to 15.4 Hz.

Figure 6: The DIMM platform at National Solar Observatory can experience a loss in stiffness at the top of the structure when a single pipe column is used for the telescope mount.

minimize seeing impact argued that the structure should also achieve rapid thermal equilibrium. Making the structure as light and as open as possible would achieve this goal also. After considering several very common tower designs it was concluded that a well braced “oil-derrick” type tower (Figure 7) produced a fundamental frequency of 42 hertz, and could be easily fabricated from common thin structural members.

2.2 ENCLOSURE DESIGN

Other than the obvious requirements for weather protection, the enclosure design was driven by the need: 1) for a reliable automated shutter, 2) to maximize ventilation of the enclosed volume, and 3) provide a wind shield for the telescope tube and mount.

Since a tight budget eliminated any consideration of an articulated enclosure, the only practical option was to consider a shutter which offered access to the full sky at all times. The McDonald Observatory has recent difficult experience with a small motorized fiberglass dome, made by Astrohaven, and was seeking alternative ideas. On the suggestion of Robert Poenisch, a member of the HET maintenance staff, we incorporated a motorized pick-up bed cover manufactured by Pace Industries, Inc. The cover resembles an overhead roll-type door which is designed to operate and seal in the horizontal, rather than vertical plane. A gentle slope was incorporated into the mounting frame on which the cover was mounted in order to facilitate rain run-off (see Figures 8 and 9). Since the cover could not seal against a truck tail gate, as originally designed, a brush seal was used as shown in Figure 10.

Figure 7: “Oil-Derrick” type structure prior to erection of access platform.

Figure 8: HET DIMM enclosure with roof shutter (Pace-Edwards pick-up bed cover) and louvers open.

Figure 9: HET DIMM enclosure with roof shutter (Pace-Edwards pick-up bed cover) closed.

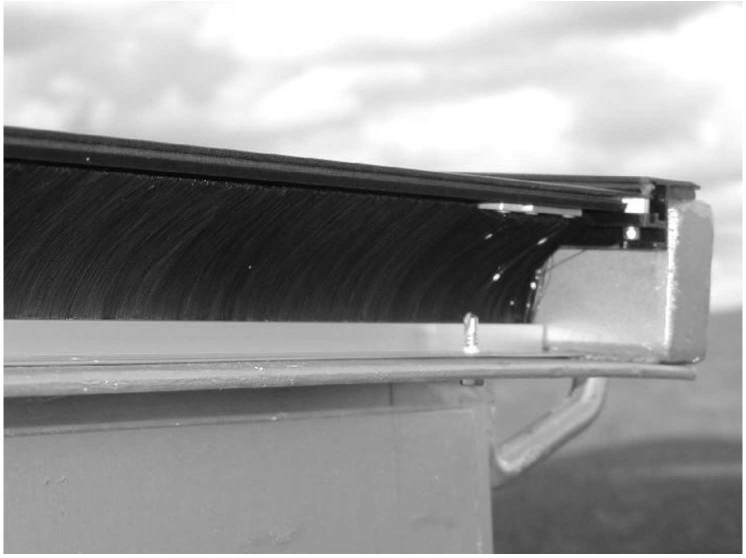

Figure 10: Detail of brush seal for shutter.

Natural ventilation of telescope enclosures has been well established as the best means to minimize enclosure seeing. Data taken at Apache Point, by Armin Rest and Chris Stubbs[3], comparing DIMM seeing inside v. outside an unventilated dome, illustrates the impact a closed enclosure can have on DIMM performance (Figure 11). It was important to protect the telescope mount from direct wind to reduce wind shake, therefore, the enclosure walls were designed to block wind from the telescope tube and mounting fork while leaving the portions above and below, including the floor, open during operation. While the wind shield blocks the horizon below 60 from zenith, this still affords a clear view of Polaris, and targets at higher elevations at Mt. Fowlkes.

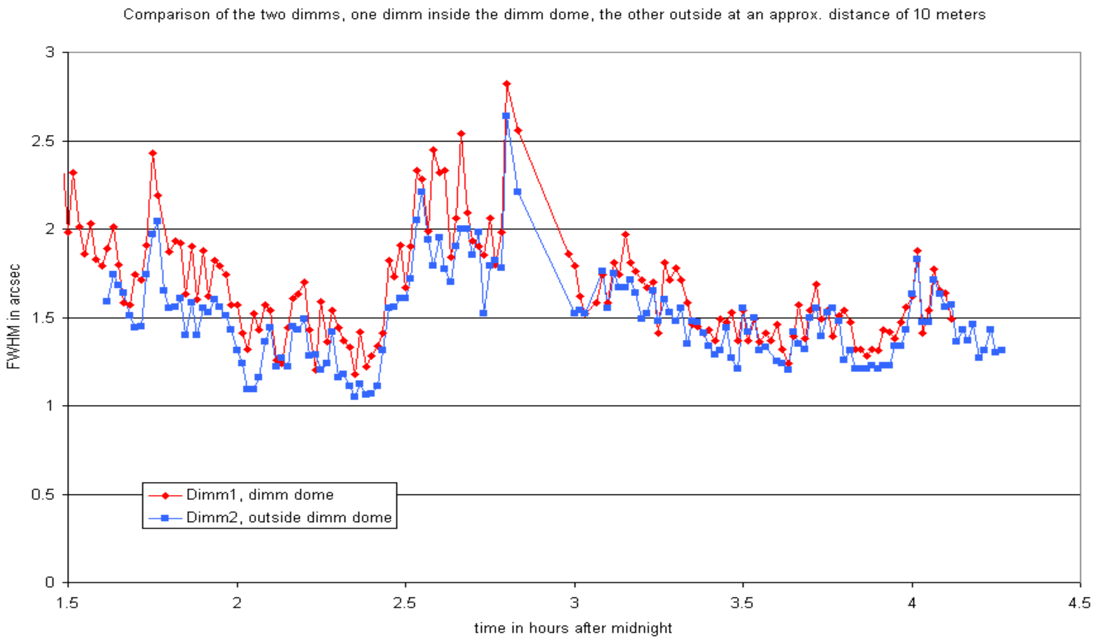

Figure 11: Data by Armin Rest and Chris Stubbs comparing DIMM measurements inside and outside a small unventilated dome.

Lessons learned from the construction of the HET alignment tower showed that isolation of an access platform from a sensitive telescope mount could be challenging. Two steps were taken to help isolate the telescope foundation from the platform foundation. First, the telescope foundation was made much more massive than the total mass of the platform, enclosure and foundation combined (30,000 lbs v. 6000 lbs). Second, the pads for the platform where made as small as possible, and placed about 1 meter from the closest edge of the telescope foundation.

3 CONSTRUCTION

Proper implementation of the design from bedrock to the telescope mounting flange was essential to realizing the calculated performance of 42 Hz. The geology of the first several meters depth of Mt. Locke can be summarized as a close fitting assembly of large boulders with packed soil between them. Rather than disturbing the well settled substrate by blasting or jack hammering, the top layer of soil and smaller rock was removed with hand tools and cleaned with a pressure washer until a clean highly irregular surface was revealed. Concrete forms were cut to conform to this irregular surface to create a massive block of concrete weighing over 30,000 lb. Thus, even the mass of the concrete, apart from a strong mechanical bond to the boulders below, would be sufficient to provide a stable foundation. In reality the bond between the concrete and the mountain essentially made them one unit. At the interface between the steel and concrete steel plates with welded anchors were embedded into the surface and the tower was welded directly to the plates, creating a solid interface to the bed rock. While the top of the tower was already close to the size of the mounting flange, a stiff structure (Figure 12) was built as an interface to assure that the stiffness of the platform was placed solidly into the telescope mounting flange.

Figure 12: A weldment assures a stiff interface between the tower and telescope. Photo taken during seeing testing prior to dome installation.

While the appearance of the tower is similar to off the shelf designs for radio and weather stations, the need for thorough bracing and solid nodes called for a custom built structure. The simplicity of the design incorporating square-cut and welded members made it an easy in-house project. The platform design was simple enough to design in-house with details left to the contract structural steel fabricator. The enclosure was a simple steel box that was also well within the capabilities of our in-house shop to fabricate. The louvers were purchased off-the-shelf and mounted in-house.

The total cost of the HET DIMM tower system, excluding in-house labor was $12,000US. Specific costs include the prefabricated platform ($5800US), the motorized shutter ($1,500US), and the motorized dampers ($1,800US).

4 CONCLUSIONS

To date the best DIMM seeing measurements recorded on either Mt. Fowlkes or Mt. Locke have been made on top of the new DIMM tower (Barker, et al, 2004)[4]. To measure any seeing effects the enclosure might have, DIMM data was taken pre and post enclosure installation. Comparative performance measurements demonstrate better performance after relocation from the ground level pen to the new platform (Figure13), and with the enclosure in place (Figure 14). Note many seeing events seen in the ground level measurements are not at the 5 meter level above the ground. In most cases the trends in the seeing are the same for both sites, with an offset due to the boundary layer seeing between 0 and 5 meters elevation. Measurements of the actual frequency, following completion confirm the analysis (Figure 15). Complete plans for the system are available on request.

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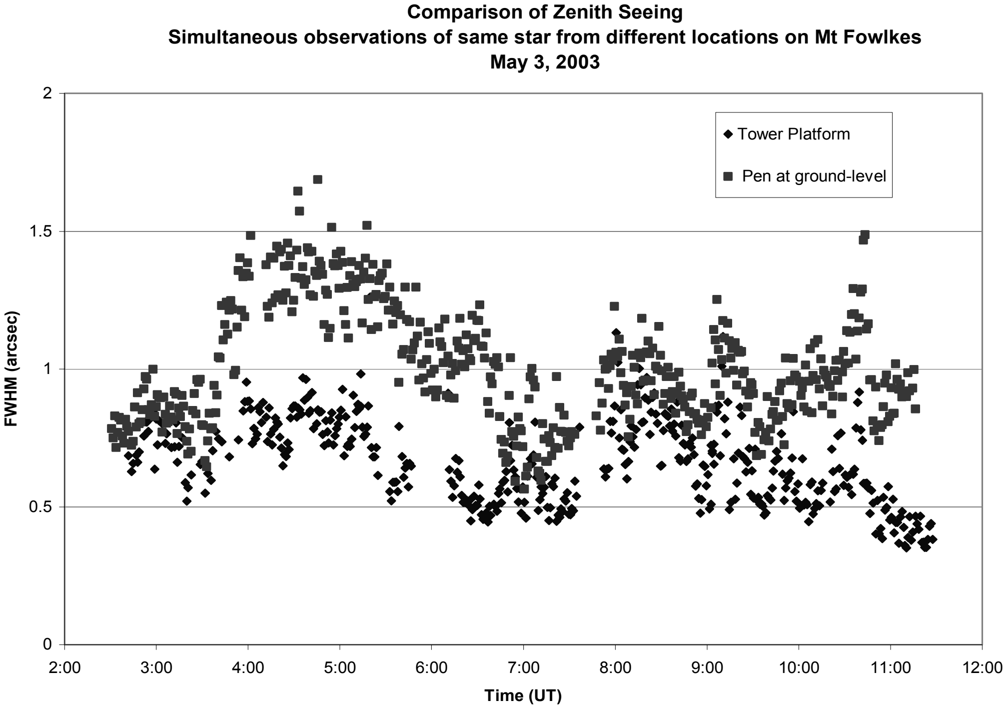


Figure 13: DIMM measurements in ground level pen compared to simultaneous measurements made from tower platform (no enclosure).

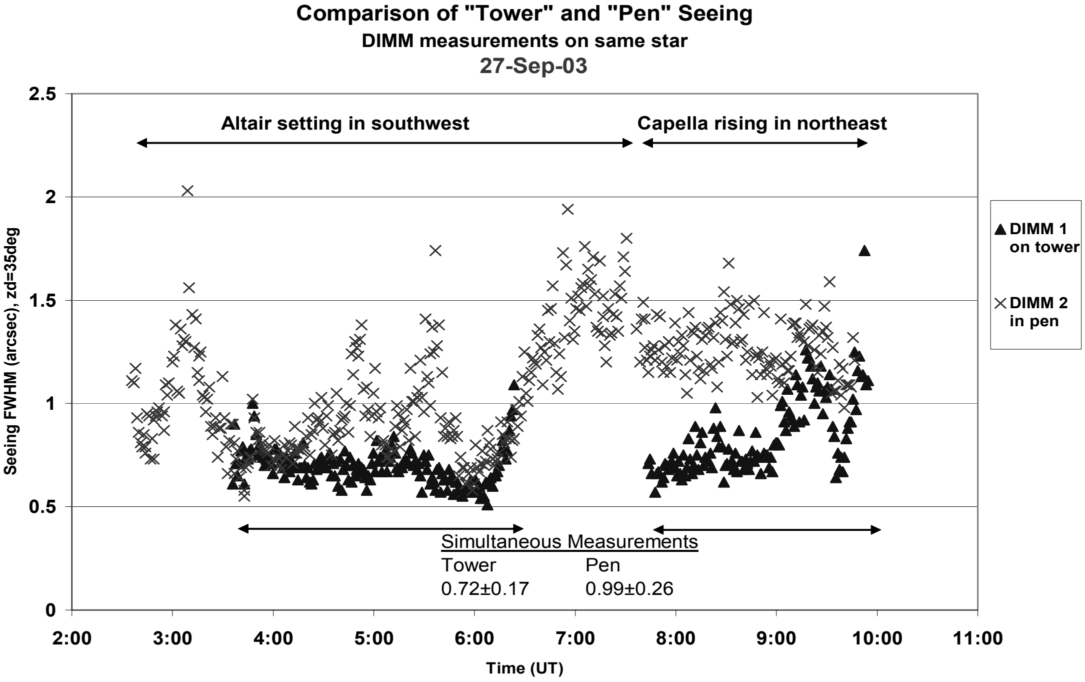
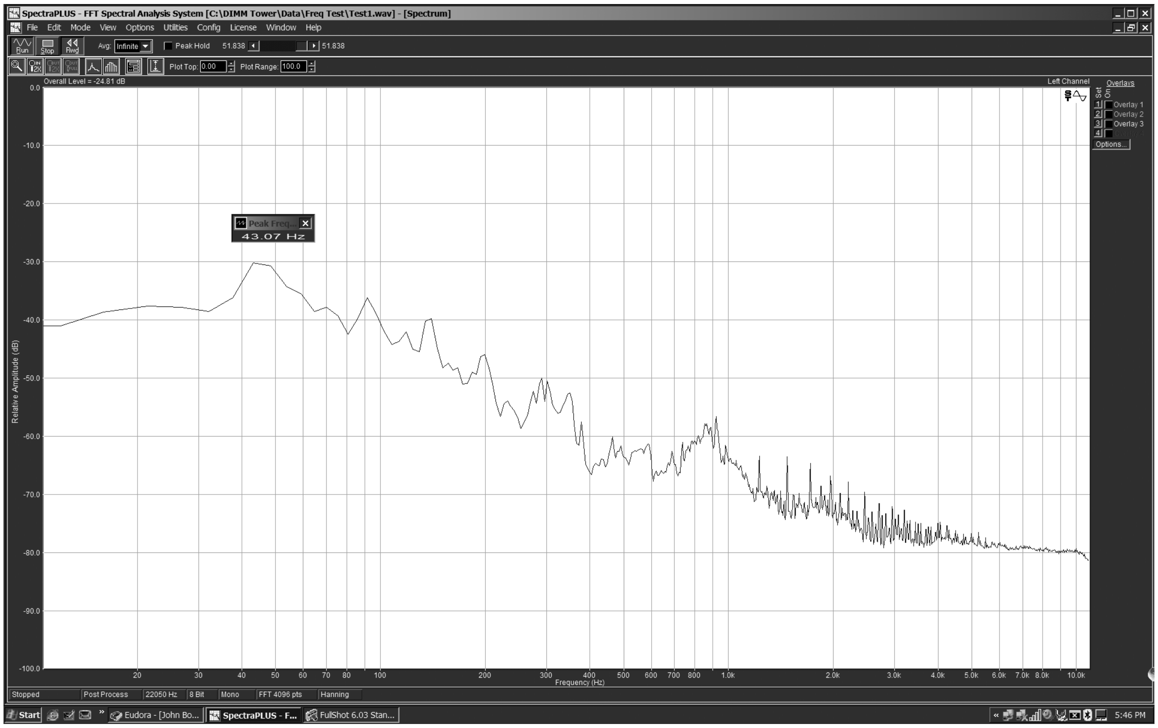


Figure 14: DIMM measurements in ground level pen compared to simultaneous measurements made from inside the enclosure on the tower.



SpectraPLUS - FFT Spectral Analysis System [C:\DIMM Tower\Data\Freq Test\Test1.wav] - [Spectrum]

Avg: Infinite

Peak Hold 51.838 51.838

Plot Top: 0.00

Plot Range: 100.0

Overall Level = -24.81 dB

Peak Freq...
43.07 Hz

Stopped | Post Process | 22050 Hz | 8 Bit | Mono | FFT 4096 pts | Hanning

Figure 15: The actual frequency of the tower was measured following full assembly, using a low-frequency audio microphone attached to the structure. The lowest vibration mode measured is 43 Hz. The lower frequency features (15-30 Hz) shown in the graph are due to background noise in the audio system.

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