Assessment of Antenna Mounting Building Structural Strength using Microtremor Analysis

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ABSTRACT. Any satellite tracking ground station requires fully steerable dish shaped antenna for fixed satellite services. Antenna foundations require special consideration, because they transmit dynamic loads to soil and foundation system, in addition to static loads due to self-weight of foundation, antenna and its accessories. Antenna foundations are of ground foundation or roof top i.e on buildings based on Radio Frequency requirements. To install antennas on existing building, the building should have required strength. To assess the building strength, building natural frequency and damping ratios are determined using Microtremor recorded data. For rotating Antennas, the required building frequency should be more than 8 Hz to avoid resonance effect of antenna structure natural frequency with servo frequency. In this study, the data is collected for building located at National Remote Sensing Centre, ISRO, Shadnagar, Hyderabad by mounting sensor at 3 locations of building. The data collected is analyzed using View 2002 software. FFT analysis is carried out to identify predominant natural modes and frequencies of the Building.

Keywords: Natural Frequency; Microtremor; Antenna Mounting Building; Structural Strength; Damping ratio

1. INTRODUCTION

An antenna is used to radiate electromagnetic energy efficiently and in desired directions. Antennas can also be classified as electrical devices which convert electric currents into radio waves and vice versa. They are broadly classified in two categories, transmitting and receiving Earth station and satellite antennas. Difference is in the mode of operation; different functions etc., as the transmitting as well as the receiving antenna. Antennas are used for Radars, Space Communication, Radio Astronomy and for Wireless Communication.

The satellite ground station requires fully steerable dish shaped antenna for fixed satellite services. The foundation for ground station antennas depends on configuration of mount, soil properties, and Radio Frequency (RF) requirements. Depending on RF requirement, antennas are installed on roof top i.e on building top or RCC tower, steel structural towers. Sometimes, antennas are installed on existing buildings as shown in figure 1 based on site requirement. For rotating antenna structures natural frequency is very important parameter. The natural frequency depends on stiffness and mass of the structure. The significant parameters which influence dynamic characteristic of building are natural frequency [1] and damping ratio [2][3] of building. These parameters are derived from ambient noise recorded in the structure of building [1-3].

Microtremor is a sophisticated instrument with tri axial velocity sensor is used to analyze the natural frequency, damping ratio of the building. The main advantages of microtremor analyses are simple, efficient and quick, yielding reliable, accurate and temporally stable estimates of frequency and
damping of the building’s vibration modes from small amplitude excitation [2][3]. Natural frequency and damping ratio is simultaneously calculated by using power spectral method [4].

1.1 Frequency Measurement with Microtremor
Using Microtremor (Model MR 2002, Make: SYSCOM Instruments SA, Switzerland), and velocity sensor, data was collected for building by mounting sensor at 3 locations 1. On top Ring beam at Anchor bolts level, 2. Terrace at cone bottom and 3. Ground floor. Details of instrument and block diagram of MR 2002 is shown in figure 2 [5]. The data collected is analyzed using View 2002 software. In order to identify the Building dominant natural modes and frequencies, FFT analysis is performed. And also frequencies calculated with excited data using rubber mallet.

1.2 Details of Instrument and Software
1.2.1 MR 2002 Micro-Tremor Instrument
It is a vibration monitoring system. MR2002 is basically made of vibration sensor (MR 2003 Tri axial velocity sensor), a device that picks up even the slightest movement. It also has vibration recorder (MR 2002 recorder unit), which possess the intelligence that controls the system and the memory, where all the data is recorded and stored. The instrument is operated together with the communication software WINCOM and the data analysis software VIEW2002.

1.2.2 VIEW2002 Software
It is the data evaluation software specifically developed for the MR2002 vibration recorder. It is a tool to view and process the data signals recorded with MR2002 and to carry out a large number of evaluations like integration, frequency analysis or calculation of damping. Software screen is shown in figure 3 [6]. Displaying of vibrations measured by sensor by three Channels, i.e. Channel 1 (X), Channel 2 (Y) and Channel 3 (Z). Amplitude spectrum is calculated using the FFT algorithm. The values displayed represent the amplitudes per Fourier term. One of the signals recorded using MR 2002 is shown in figure 4. And FFT plot for the signal recorded is shown in figure 5.
1. MR2002-CE Recorder Unit
2. MS2003+ Velocity sensor on a mounting plate
3. Power cable
4. Sensor cable Communication cable (RS-232)
5. Carrying case

**Figure 2:** Details of Instrument and Block Diagram of MR 2002

**Figure 3:** View 2002 Software Screen.
Figure 4: Signal Recorded using MR 2002 for Event 9
2. DATA ANALYSIS

2.1 Microtremor Data Recorded for Existing Building

Building located at NRSC, Shadnagar, Hyderabad is tested using Microtremor equipment tri axial sensor mounted on Building top ring beam (2 locations – Centre of ring beam), 1st floor slab and ground floor. Antenna mounting building considered for measurement is shown in figure 6. Test setup on ring beam shown in figure 7. The data collected is analyzed, for plotting FFT.

Sensor data collected by mounting on four parts, as shown below.

i. Sensor on Ring beam - R1
ii. Sensor on Ring beam – R2
iii. Sensor on Building 1st Floor Slab (bottom of Cone) (T1 & T2)
iv. Sensor Mounted on Ground Floor

From Channel 1(X), Channel 2(Y), and Channel 3(Z), data is collected for approximately 10 to 15 minutes (X, Y, Z signals in horizontal and vertical directions, respectively) for each event.
2.1.1. **Velocity Sensor on Ring Beam – R1**

Sensor mounted on ring beam at two locations diagonally opposite R1 and R2. Sensor locations are shown in figure 8. The data collected for 10 minutes and 20 events recorded. The damping and frequency for dominant decayed signals analysed and tabulated in Table 2.
Figure 8: Top Ring Beam showing Sensor Locations

| Signals in R1 | Channel X in Hz | Channel Y in Hz | Channel Z in Hz | Remarks |
|---------------|----------------|----------------|----------------|---------|
| 1             | -              | -              | 16.70          | Signal not recorded properly for Channel X and Y. |
| 2             | 17.09          | -              | -              |         |
| 3             | 14.19          | 16.70          | 16.94          | -       |
| 4             | 16.46          | 17.07          | 16.53          | -       |
| 5             | 15.01          | 16.75          | 17.07          | -       |
| 6             | 16.70          | 13.79          | 16.94          | -       |
| 7             | 16.77          | 16.72          | 17.02          | -       |
| 8             | 16.99          | 16.67          | 17.02          | -       |
| 9             | 13.82          | 16.85          | 16.85          | -       |
| 10            | 16.67          | 17.02          | 17.02          | -       |
| 11            | 14.58          | 19.19          | 17.02          | -       |
| 12            | 17.02          | 16.82          | 17.02          | -       |
| 13            | 14.36          | 12.48          | 16.77          | -       |
| 14            | 14.43          | 17.87          | 17.02          | -       |
| 15            | 17.11          | 16.8           | 17.07          | -       |
| 16            | 15.33          | 12.13          | 16.82          | -       |
| 17            | 14.18          | 24.51          | 16.8           | -       |
| 18            | 14.21          | 11.82          | 13.48          | -       |
| 19            | 14.11          | 11.79          | 13.48          | -       |
| 20            | 15.19          | 14.53          | 15.11          | -       |
### Table 2: Frequency and Damping in Dominant Decayed Signal

| Channel | Frequency in Hz | Damping | Signals | Remarks |
|---------|----------------|---------|---------|---------|
| Ch1 - X | 14.5 Hz        | 3.6 %   | Event 18| Dominant decayed signal from 16.95 to 17.5 sec |
| Ch2 - Y | 12.8 Hz        | 3.0 %   | Event 18| Dominant decayed signal from 20 to 21 sec |
| Ch3 - Z | 15.7 Hz        | 3.8 %   | Event 18| Dominant decayed signal from 15.6 to 16.2 sec |

The Frequency and Damping plot for decayed signals shown in figure 9.

According to Zhang and Cho [7] that the limit damping ratio has 2–5% for standard design. Based on Microtremor data analysis, the damping ratio obtained is 3 to 3.8%.

#### 2.1.2. Velocity Sensor on Ring beam – R2

The data collected for 13 minutes and 25 events recorded. The sample signals recorded for 30 sec (each event). The frequencies of all events (FFT Analysis) calculated using View 2002 software and tabulated in table 3.

### Table 3: Frequencies of all events for 3 Channels (X, Y & Z).

| Signals in R2 | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|---------------|-----------------|-----------------|-----------------|
| 1             | 13.33           | 17.14           | 20.36           |
| 2             | 16.82           | 16.53           | 16.75           |
| 3             | 14.23           | 16.50           | 24.78           |
| 4             | 16.75           | 17.14           | 16.82           |
| 5             | 19.41           | 24.02           | 24.88           |
| 6             | 14.33           | 13.70           | 16.09           |
| 7             | 16.89           | 17.04           | 16.85           |
| 8             | 16.87           | 17.36           | 16.85           |
| 9             | 14.58           | 17.14           | 24.66           |
| 10            | 16.55           | 17.14           | 17.07           |
| 11            | 16.65           | 24.10           | 24.78           |
| 12            | 16.85           | 16.87           | 16.82           |
| 13            | 16.82           | 17.14           | 16.82           |
| 14            | 16.75           | 17.07           | 24.73           |
| 15            | 16.80           | 17.07           | 17.07           |
| 16            | 16.82           | 16.99           | 16.94           |
| 17            | 17.04           | 17.04           | 65.92           |
| 18            | 16.94           | 17.04           | 65.06           |
| 19            | 16.77           | 16.53           | 16.48           |
| 20            | 16.72           | 15.84           | 16.38           |
Figure 9: Damping & Frequency Plot for dominant Decayed Signal
2.1.3. Velocity Sensor on FIRST FLOOR SLAB - T1
The data collected for 10 minutes and 20 events recorded. The sample signals recorded for 30 sec (each event). The frequencies of all events (FFT Analysis) calculated using View 2002 software and tabulated in table 4.

2.1.4. Velocity Sensor on FIRST FLOOR SLAB – T2
The data collected for 12 minutes and 11 events recorded. For this location, each event data collected for 60 sec. The sample signals recorded for 60 sec (each event). The frequencies of all events calculated using View 2002 software and tabulated in table 5.

| Signals in T1 | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|---------------|-----------------|-----------------|-----------------|
| 1             | 13.89           | 17.11           | 13.92           |
| 2             | 17.31           | 24.46           | 49.98           |
| 3             | 13.28           | 24.44           | 15.55           |
| 4             | 1685            | 13.23           | 12.65           |
| 5             | 12.50           | 17.58           | 14.01           |
| 6             | 14.16           | 17.26           | 50.02           |
| 7             | 13.75           | 15.60           | 50.02           |
| 8             | 13.18           | 24.54           | 28.22           |
| 9             | 13.35           | 17.02           | 11.38           |
| 10            | 14.58           | 17.63           | 14.58           |
| 11            | 14.45           | 15.14           | 16.55           |
| 12            | 14.92           | 14.84           | 14.99           |
| 13            | 13.31           | 16.67           | 14.45           |
| 14            | 16.60           | 24.41           | 15.06           |
| 15            | 13.55           | 16.31           | 16.26           |
| 16            | 14.40           | 14.84           | 13.65           |
| 17            | 13.77           | 14.70           | 12.89           |
| 18            | 13.67           | 16.33           | 13.87           |
| 19            | 15.11           | 19.60           | 19.63           |
| 20            | 25.51           | 24.37           | 13.79           |

| Signals in T1 | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|---------------|-----------------|-----------------|-----------------|
| 1             | 14.22           | 15.95           | 15.83           |
| 2             | 15.60           | 17.36           | 15.98           |
| 3             | 15.98           | 17.38           | 15.98           |
| 4             | 14.05           | 17.40           | 17.24           |
| 5             | 14.51           | 15.98           | 16.70           |
| 6             | 14.38           | 17.16           | 16.03           |
| 7             | 15.03           | 17.52           | 16.04           |
| 8             | 15.88           | 17.17           | 15.98           |
| 9             | 13.95           | 13.95           | 15.89           |
| 10            | 14.97           | 16.96           | 16.86           |
| 11            | 16.02           | 17.09           | 16.02           |
2.1.5. Velocity Sensor on GROUND

The data collected for 10 minutes and 20 events recorded. The sample signals recorded for 30 sec (each event). The frequencies calculated using View 2002 software and tabulated in Table 6.

| Signals on Ground | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|-------------------|-----------------|-----------------|-----------------|
| 1                 | 50.07           | 50.07           | 50.07           |
| 2                 | 14.09           | 50.07           | 50.07           |
| 3                 | 13.89           | 25.07           | 51.46           |
| 4                 | 14.01           | 12.04           | 50.07           |
| 5                 | 50.05           | 50.05           | 50.05           |
| 6                 | 50.02           | 50.02           | 50.02           |
| 7                 | 50.02           | 50.02           | 50.02           |
| 8                 | 50.08           | 50.08           | 50.08           |
| 9                 | 50.02           | 50.02           | 50.02           |
| 10                | 13.50           | 16.58           | 16.04           |
| 11                | 15.97           | 15.58           | 15.97           |
| 12                | 14.26           | 15.97           | 17.07           |
| 13                | 46.26           | 46.34           | 16.8            |
| 14                | 14.40           | 17.14           | 16.8            |
| 15                | 12.65           | 15.97           | 15.97           |
| 16                | 13.38           | 17.11           | 16.99           |
| 17                | 12.08           | 16.02           | 17.26           |
| 18                | 13.48           | 15.97           | 17.04           |
| 19                | 50              | 50              | 50              |
| 20                | 15.97           | 15.97           | 15.97           |

Data recorded by hitting the top cone and first floor slab using rubber hammer. Frequency analysis is carried out and given in table 7 and table 8.

**Table 7: Frequency of Events after hitting with Rubber Hammer**

| Signals | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|---------|-----------------|-----------------|-----------------|
| 1       | 33.50           | 21.68           | 33.47           |
| 2       | 13.75           | 16.53           | 22.53           |
| 3       | 48.39           | 31.08           | 44.68           |
| 4       | 13.28           | 15.04           | 12.01           |
| 5       | 13.89           | 16.02           | 25.20           |

**Table 8: Frequency of First floor Slab by hitting with Rubber Hammer**

| Signals | Channel X in Hz | Channel Y in Hz | Channel Z in Hz |
|---------|-----------------|-----------------|-----------------|
| 1       | 14.36           | 23.32           | 15.82           |
| 2       | 49.98           | 50.00           | 50.02           |
| 3       | 49.98           | 43.14           | 43.14           |
| 4       | 50.00           | 43.16           | 43.16           |
| 5       | 49.85           | 43.12           | 43.12           |
| 6       | 43.12           | 43.09           | 43.12           |
3. CONCLUSIONS
The followings conclusions drawn from Microtremor recorded data analysis.

1. The building is stiff and overall natural frequency is more than 8Hz.
2. The minimum frequency obtained is 11.38Hz (Ch3–Z) with data collected by hitting the first floor slab @T1 Location.
3. Ch1 – X Channel data-12.08Hz,
   Ch2 – Y Channel data- 11.79Hz,
   Ch3 – Z Channel data- 11.38Hz.
4. The building is safe and having required stiffness to take antenna load. Hence Antenna may be installed on building.

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REFERENCES
1. Gosar, “Site effects and soil-structure resonance study in the Kobarid basin (NW Slovenia) using microtremors”, Nat. Hazards Earth SystSci., 10, 761–772, 2010
2. M. Herak, “Overview of recent ambient noise measurements in Croatian free-field and in buildings”, Geofizika, vol.28, 2011.
3. Herak, M., Recent applications of ambient vibration measurements in Croatia, in Increasing Seismic Safety by Combining Engineering Technologies and Seismological Data, edited by Mucciarelli, M., Herak, M. and Cassidy, J., Springer – NATO series, Dordrecht, 281–292, 2009.
4. Sungkono, Dwa D. Warnana, Triwulan, W. Utama, Evaluation of Buildings Strength from Microtremor Analyses, IJCEE-IJENS Vol: 11 No: 05, 116605-8383 IJCEE-IJENS ©October 2011 IJENS
5. User manual MR 2002-CE WINCOM Version 2 06.01.2007.
6. VIEW 2002 User’s Manual 10.1.2009, ZIEGLER consultants
7. Z. Zhang, C. Cho, Experimental Study on Damping Ratios of in-situ Buildings, International Journal of Engineering and Applied Sciences5:4 2009.
8. Masanori Iiba, Morimasa Watakabe, Atsushi Fujii, Shin Koyama, Shigeki Sakai, Koichi Morita, A Study on Dynamic Soil-structure Interaction Effect Based on Microtremor Measurement of Building and Surrounding Ground Surface, Proceedings Third UJNR workshop on Soil-Structure Interaction, March 29-30, 2004, Menlo Park, California, USA.
9. Toshiharu ARAKAWA and Kazuya YAMAMOTO, Frequencies and damping Ratios of a High Rise Building Based on Microtremor Measurement, 13th World Conference on Earthquake Engineering, WCEE, 2004.