ngVLA Electronics Memo No. 6

# A First Order Reliability Model for a VLA Antenna: Mining MainSaver and JIRA for VLA Reliability Data

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**Abstract**

Reliability models for an average VLA antenna were constructed using the MainSaver and JIRA maintenance databases. The MainSaver antenna reliability model produces $MTBF = 247$ hours, while the JIRA model produces $MTBF = 226$ hours.

## 1 Introduction

With the advent of designs for new, large, radio telescope arrays, the importance of reliability engineering is rising. Minimizing operational costs, including maintenance, is a critical part of these new arrays. Even coarse analyses of field reliability data for older NRAO telescopes will allow us to make more informed decisions for the design of ngVLA and future telescope arrays.

Toward that end, we will examine VLA antenna reliability, for as many antennas as possible. The maintenance databases used for issuing work-orders and monitoring status provide a rough source for field reliability data. A few data gathering shortcuts are necessary, given the complex database queries involved. First, the ticket counts for a given antenna are a sum of all maintenance tickets assigned to that antenna, encompassing all sub-systems present on the antenna. Second, it is assumed that each maintenance ticket describes a failure. Even with these simplifications, the records available in the maintenance databases are not completely suitable. Data censoring is a complicating factor for reliability analysis, and NRAO's maintenance databases contain both interval censored data (uncertainty about exact failure time), and left censored data (failure time is only known to be before a certain time).

Two different maintenance databases are available for post-EVLA maintenance tickets. MainSaver contains all data from inception until August of 2018, and JIRA contains all tickets from August 2018 until July 2020. In addition to the data censoring, there are omissions, incorrect dates, and other data quality problems present in these databases. Hence, we are limited to presenting the most basic reliability models, without any ability to determine model quality.

## 2 MainSaver

The first data set, acquired from the MainSaver database, includes data from May 2006 through June 2018. The failure count for each antenna in MainSaver is shown below in Table 1.

As is apparent from the table, we were unable to retrieve failure data for every EVLA antenna. The fifteen available data points still allow for valid, if incomplete, estimation of the general antenna failure rate. For this subset of antennas, the mean number of failures is $\mu_{ms} \approx 429$, and the standard deviation is $\sigma_{ms} \approx 60$. There is substantial variability between antennas, so we will use the mean number of failures rather than picking any single antenna as exemplar.

| Sub-system | Failures | Time Start | Time Stop | Total Time (Hours) |
|---|---|---|---|---|
| EA01 | 514 | 05/01/2006 | 06/01/2018 | 105936 |
| EA02 | 408 | | | |
| EA03 | 382 | | | |
| EA04 | 443 | | | |
| EA05 | 456 | | | |
| EA10 | 326 | | | |
| EA11 | 351 | | | |
| EA12 | 401 | | | |
| EA13 | 527 | | | |
| EA14 | 517 | | | |
| EA15 | 371 | | | |
| EA25 | 440 | | | |
| EA26 | 396 | | | |
| EA27 | 450 | | | |
| EA28 | 451 | | | |

Table 1: VLA antenna failures from MainSaver

Using an exponential model, we can roughly estimate the reliability parameters for an EVLA antenna and present a function for the reliability $R(t)$:

$$\lambda_{ms} = \frac{\text{failures}}{\text{hours}} = \frac{429}{105936} = \frac{4.05 \times 10^{-3} \text{ failures}}{\text{hour}}$$

$$MTBF_{ms} = \frac{1}{\lambda_{ms}} = \frac{1}{4.05 \times 10^{-3}} = 247 \text{ hours}$$

$$R_{ms}(t) = e^{-\lambda_{ms} t} = e^{-4.05 \times 10^{-3} t}$$

Figure 1 shows the MainSaver antenna reliability plotted for 1000 hours.

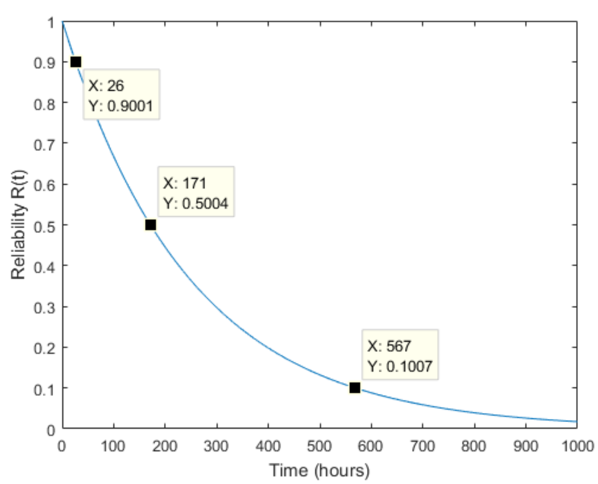


Figure 1: EVLA Antenna Reliability Curve, MainSaver data

Stated another way, the MainSaver antenna reliability curve allows us to predict:

- 10% of EVLA antennas will have failed by $\approx$ 26 hours (L10).
- 50% of EVLA antennas will have failed by $\approx$ 171 hours (L50).
- 90% of EVLA antennas will have failed by $\approx$ 567 hours (L90).

# 3 JIRA

The second data set, acquired from JIRA, covers the time period from August 2018 until July 2020. The failure count for each antenna in JIRA is shown below in Table 2.

| Sub-system | Failures | Time Start | Time Stop | Total Time (Hours) |
|---|---|---|---|---|
| EA01 | 85 | 08/01/2018 | 07/01/2020 | 16800 |
| EA02 | 89 | | | |
| EA03 | 65 | | | |
| EA04 | 62 | | | |
| EA05 | 77 | | | |
| EA10 | 62 | | | |
| EA11 | 69 | | | |
| EA12 | 67 | | | |
| EA13 | 53 | | | |
| EA14 | 80 | | | |
| EA15 | 73 | | | |
| EA25 | 119 | | | |
| EA26 | 63 | | | |
| EA27 | 76 | | | |
| EA28 | 77 | | | |

Table 2: VLA antenna failures from JIRA

The JIRA database is generally considered to contain more carefully curated data than MainSaver, so it will provide an excellent sanity check for the MainSaver data. The mean number of failures for an EVLA antenna using the JIRA data is $\mu_{jira} \approx 74$, with standard deviation $\sigma_{jira} \approx 16$.

Using the JIRA data, we can recalculate the reliability parameters for an EVLA antenna and present another model for reliability $R(t)$:

$$\lambda_{jira} = \frac{\text{failures}}{\text{hours}} = \frac{74}{16800} = \frac{4.40 \times 10^{-3} \text{ failures}}{\text{hour}}$$

$$MTBF_{jira} = \frac{1}{\lambda_{jira}} = \frac{1}{4.40 \times 10^{-3}} = 226 \text{ hours}$$

$$R_{jira}(t) = e^{-\lambda_{jira} t} = e^{-4.40 \times 10^{-3} t}$$

Figure 2 shows the JIRA antenna reliability plotted for 1000 hours.

The JIRA antenna reliability curve allows us to predict:

- 10% of EVLA antennas will have failed by ≈ 24 hours (L10).
- 50% of EVLA antennas will have failed by ≈ 156 hours (L50).
- 90% of EVLA antennas will have failed by ≈ 519 hours (L90).

# 4 Conclusion

Field failure data, acquired from MainSaver and JIRA, was used to build independent reliability models for a VLA antenna post-EVLA.

The MainSaver data set produced a reliability model with $MTBF = 247$ hours, while the JIRA data set produced a reliability model with $MTBF = 226$ hours. These are extremely similar models derived from independent sources, and this similarity provides an excellent sanity check for each model.

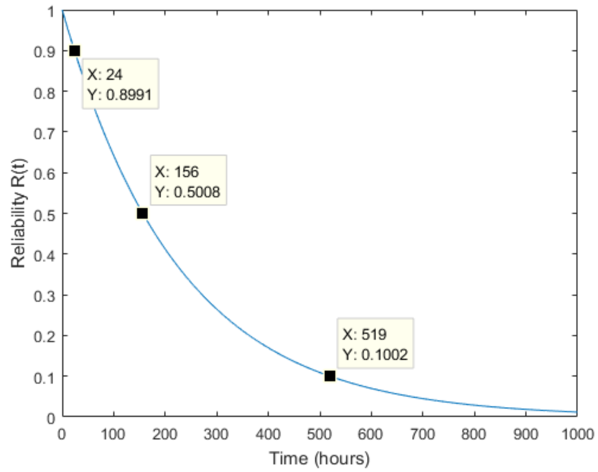


Figure 2: EVLA Antenna Reliability Curve, JIRA data

As mentioned previously, there are systemic data quality errors in both data sets, so this should be considered as only the most elementary reliability engineering analysis that can provide useful insight. Additional investigation is necessary to produce a more rigorous check on the model quality.