RFI 2022

A Global Overview of the Radio Frequency Interference (RFI) Sources as Detected by the MeerKAT Telescope

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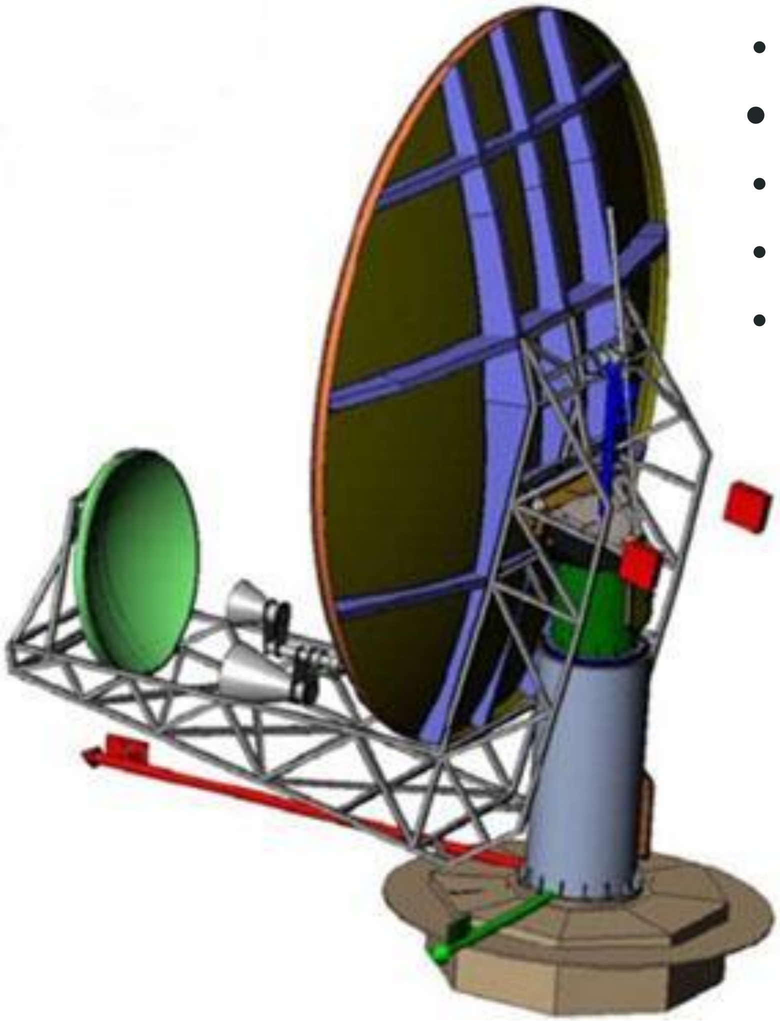
Overview

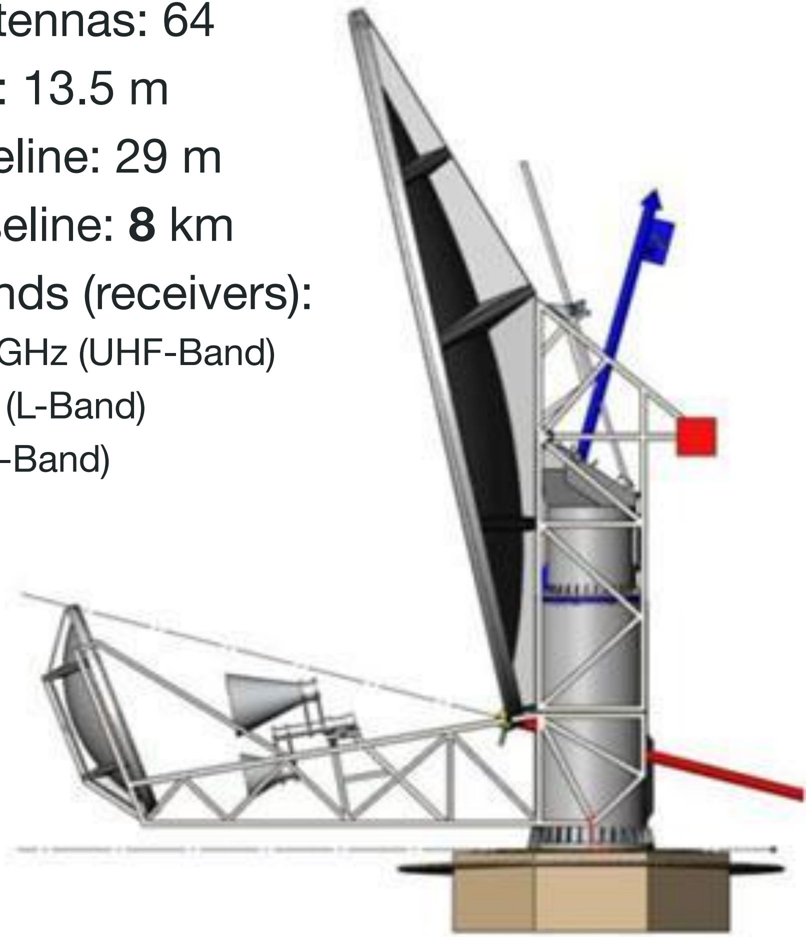
- MeerKAT Telescope
- Why this work?
- Use Case
- MeerKAT RFI Data Structure
- KATHPRFI Framework
- Results
- Conclusion

This presentation will cover some work published in I. Sihlangu et al, J. of Astronomical Telescopes, Instruments, and Systems, 8(1), 011003 (2021).

MeerKAT



- Number of antennas: 64
- Dish diameter: 13.5 m
- Minimum baseline: 29 m
- Maximum baseline: **8** km
- Frequency bands (receivers):
  - 0.58 - 1.015 GHz (UHF-Band)
  - 1 - 1.75 GHz (L-Band)
  - 2 - 4 GHz (S-Band)



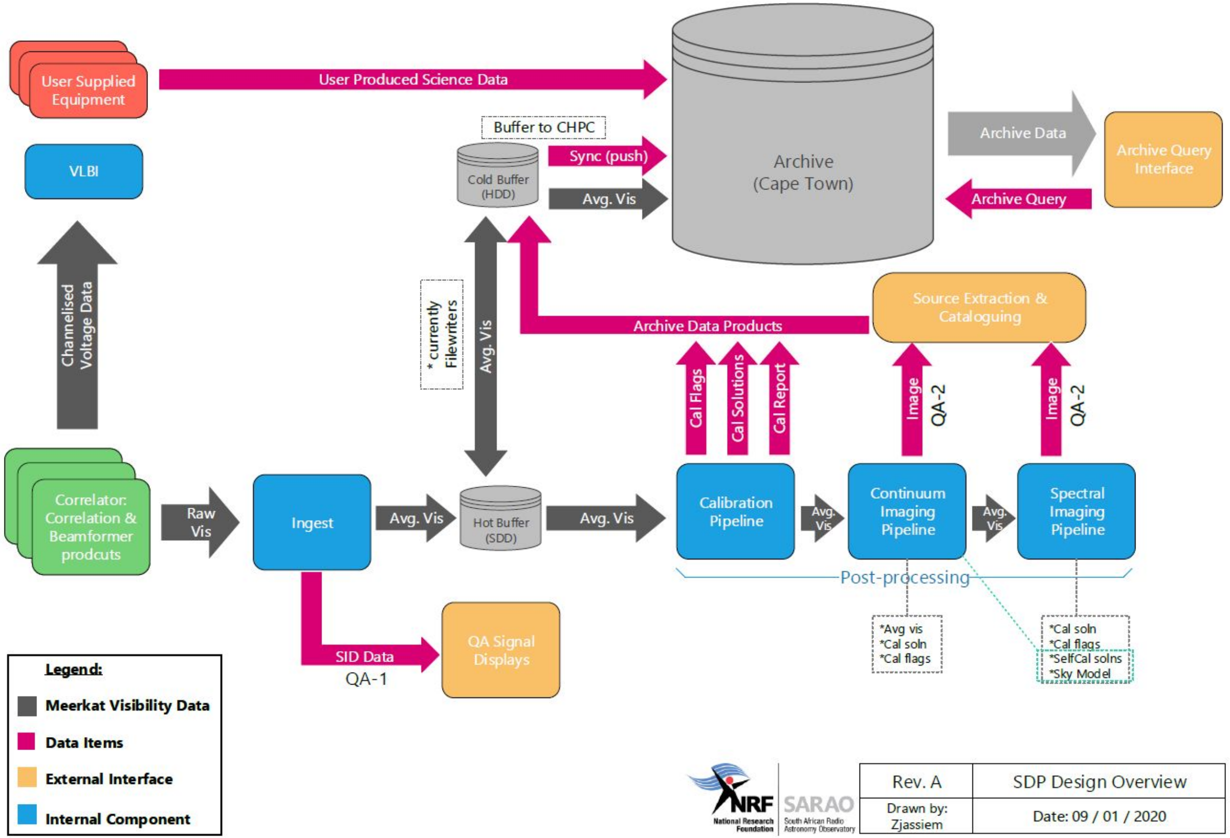
Why this work?

- Understanding the Radio Frequency Interference (RFI) environment for astronomy sites is the drive for this work
- RFI Plagued radio astronomy which potentially might be as bad or worse by the time the Square Kilometre Array (SKA) comes up
- Understand Internal (generated by instruments) or External (originates from intentional or unintentional radio emission generated by man)

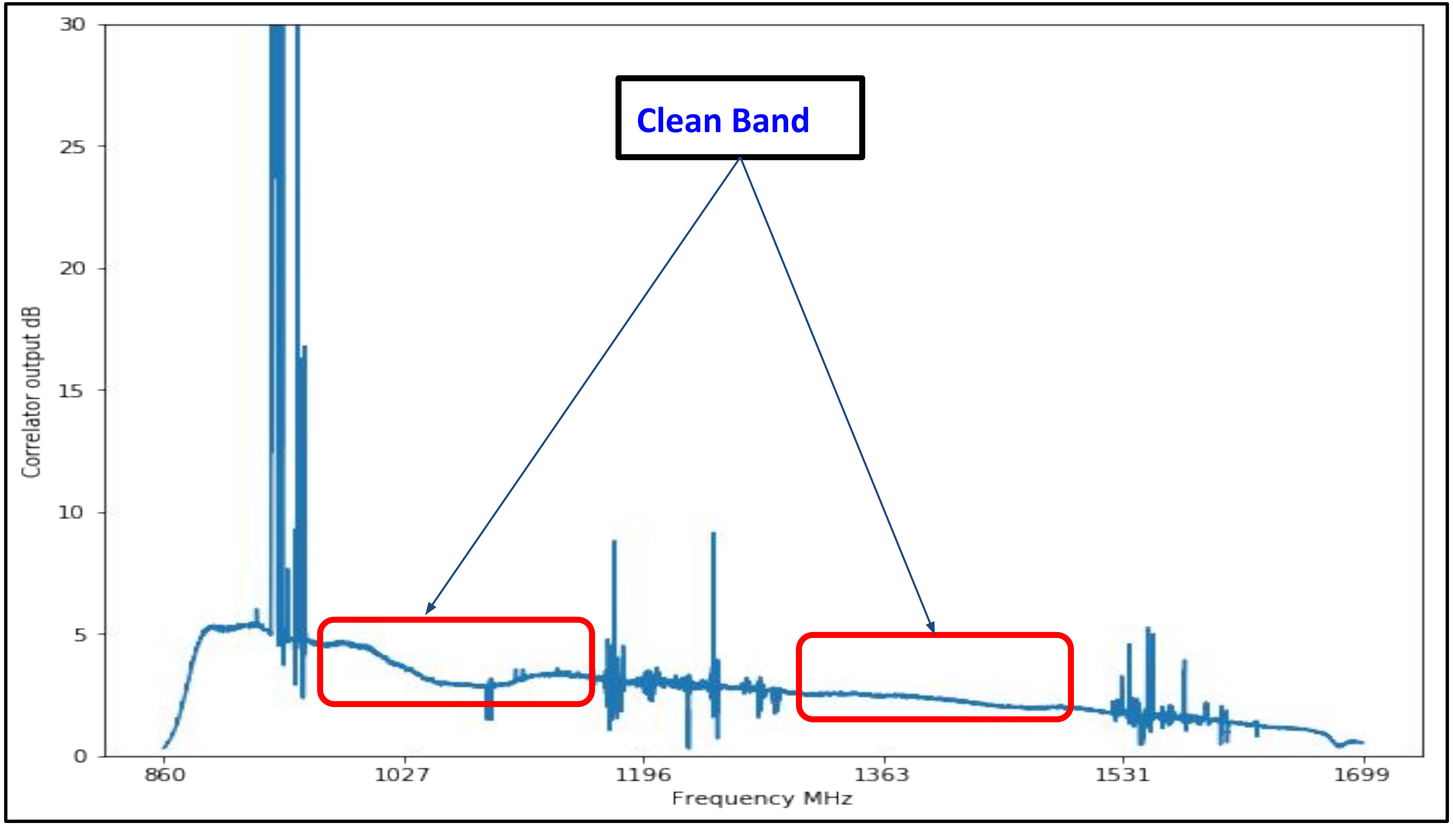
Use case

- **Astronomers**: to optimise flagging, and planning observations
- **Operations**: to schedule desired critical observations and
- **RFI-WG/Stakeholders**: by providing an alert system if level of RFI goes beyond a critical threshold

MeerKAT Data Processing Flow



Typical MeerKAT Bandpass with RFI Spikes



MeerKAT RFI Flags

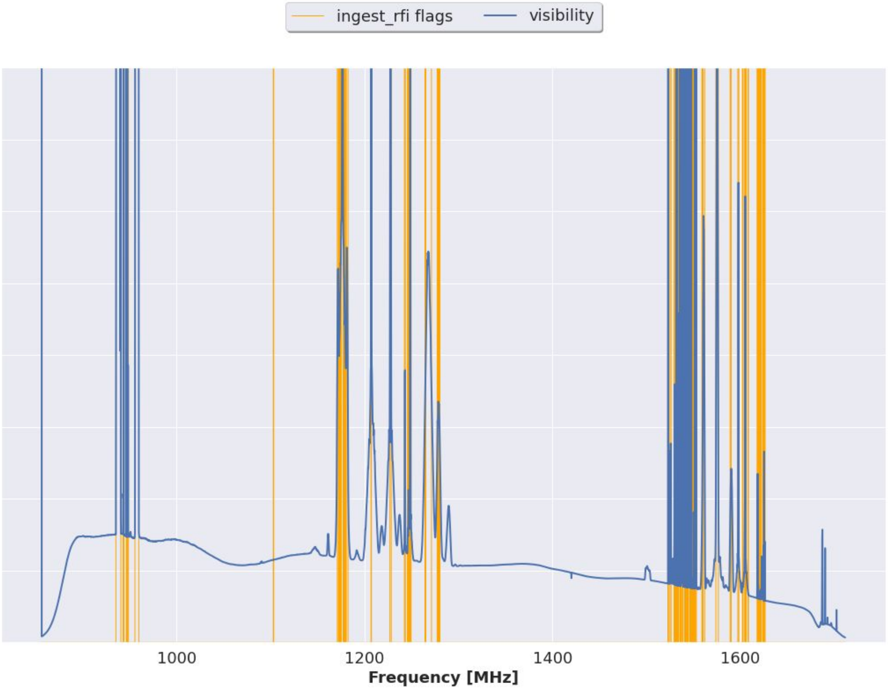
- Flag files are built around the concept of three-dimensional flag array [T, F, B].
- Flags are stored as 8-bits (uint8), where each bit is a different kind of flag.

Value	Name
1	reserved0
2	static
4	cam
8	data_lost
16	ingest_rfi
32	predicted_rfi
64	cal_rfi
128	postproc

Data processing flow

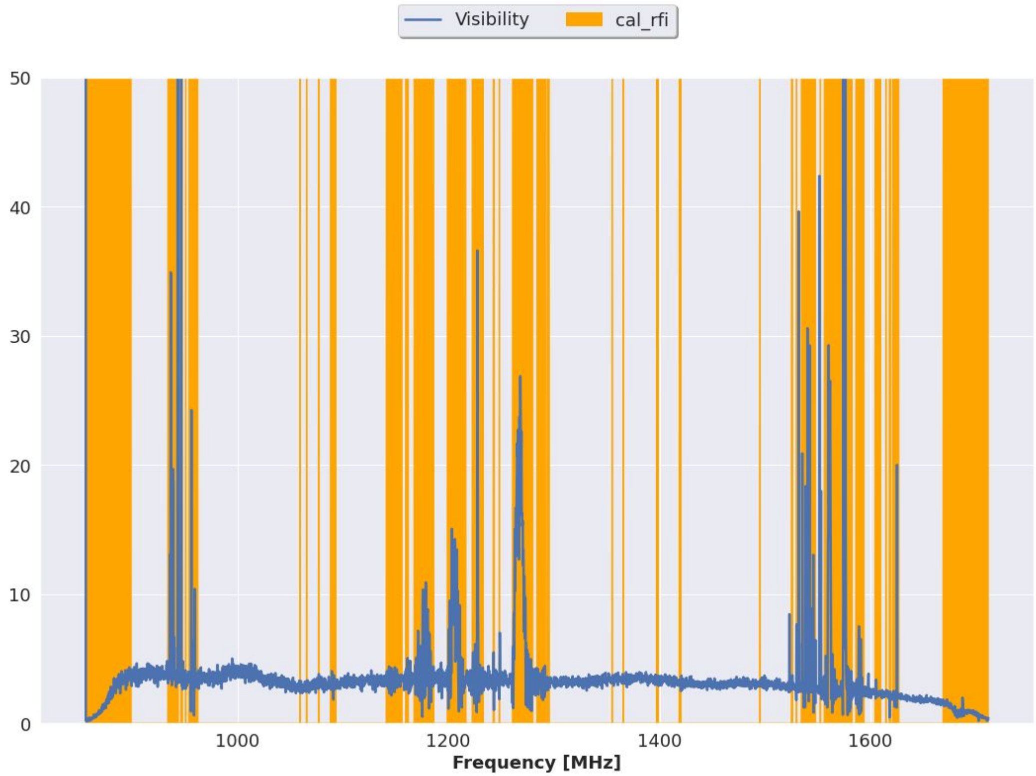
ingest_rfi

- Produced at the ingest step (i.e L0), and is the high time resolution RFI detection
- Uses simple Mean Absolute Deviation (MAD) statistics, runs along **Frequency** axis
- Flagged CBF dumps are excised (removed) from the average of SDP dump
- Excision in influenced by static, cam and ingest_rfi flags

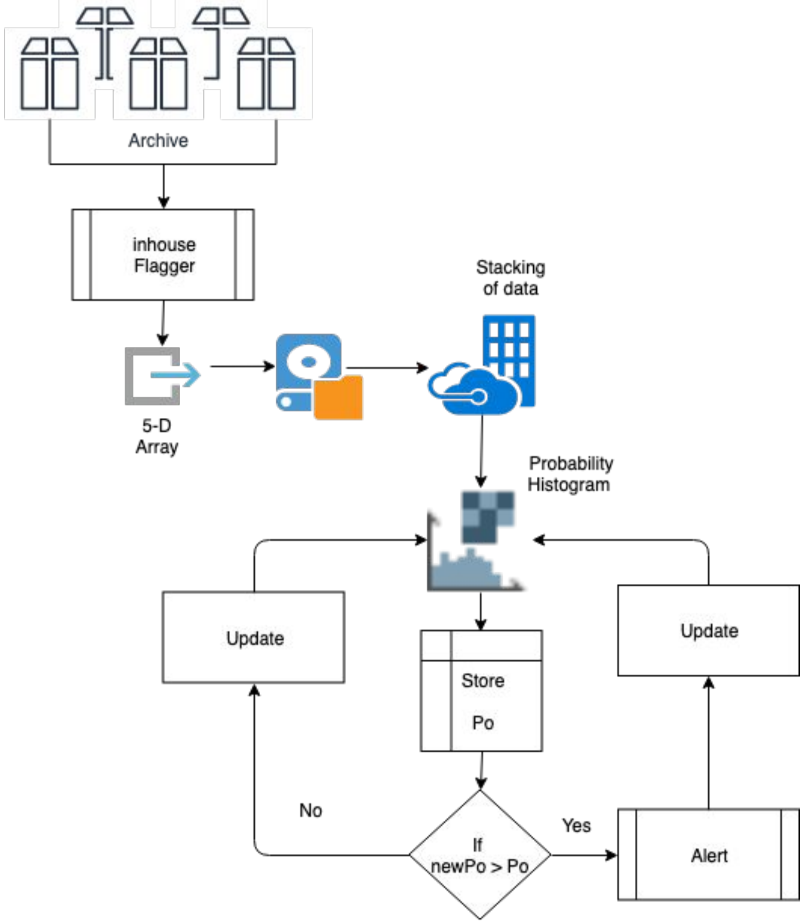


cal_rfi

- Based on the classic AOflagger (Offringa et al. 2012)
- Runs along **Time** and **Frequency**
- Each baseline is treated differently
- The flagger, first find a smooth background on previously un-flagged data and then sum-threshold



(Meer)KAT HISTORICAL PROBABILITIES OF RFI [KATHPRFI]



Dimensions = [T, F, B, Az, El]
= [24, 4096, 2016, 24, 8]

- Approximately 850 hours of observation was used.
- Equivalent to 106 TB

Probability Calculations:

Probability in a given voxel:

$$P(RFI|t,v,b,el,az) = \frac{\alpha_{t,v,b,el,az}}{\alpha_{t,v,b,el,az} + \beta_{t,v,b,el,az}}$$

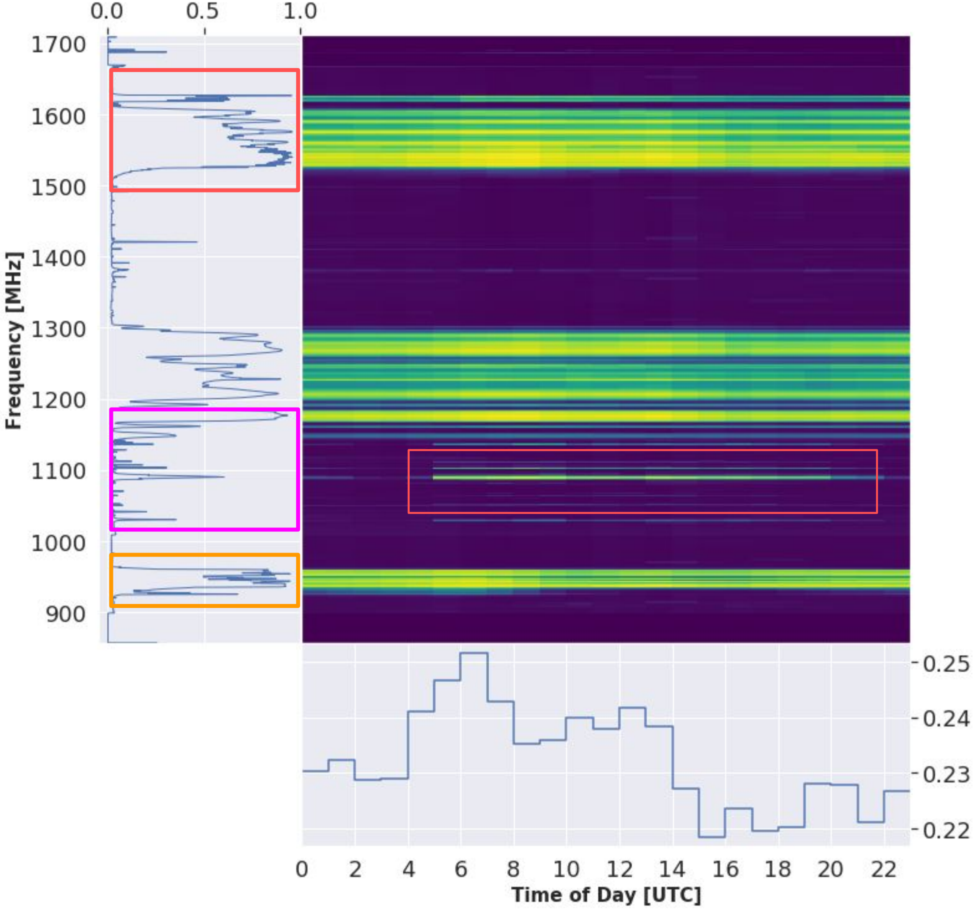
Probability for a given dimension:

$$P(RFI|v) = \frac{\sum_{t,b,el,az}(\alpha_v)}{\sum_{t,b,el,az}(\alpha_v + \beta_v)}.$$

α - Number of RFI points in a voxel

β - Number of non-RFI points in a voxel

Time-Frequency Dependency



- 3 Major culprits are: GSM, DMEs and GPS Satellite
- Observe RFI increase during the day
- The increase correlates with when human activities start
- There exist a correlation between the 1090 MHz DME frequency and time of the day
- Around 30% of the L-band is affected by the RFI

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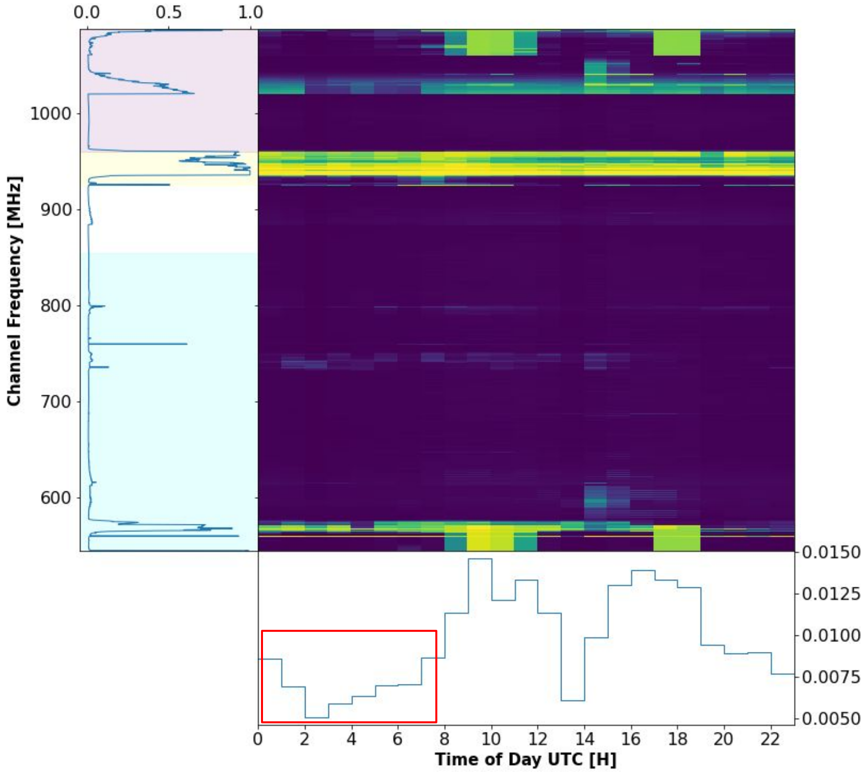
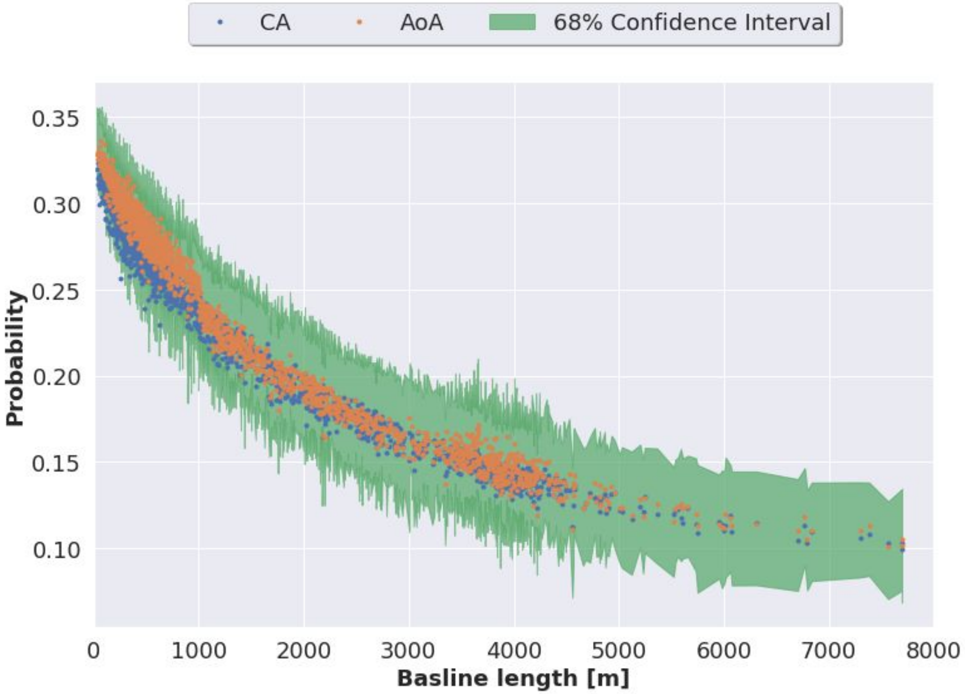
Known UHF-RFI



Baseline Dependency



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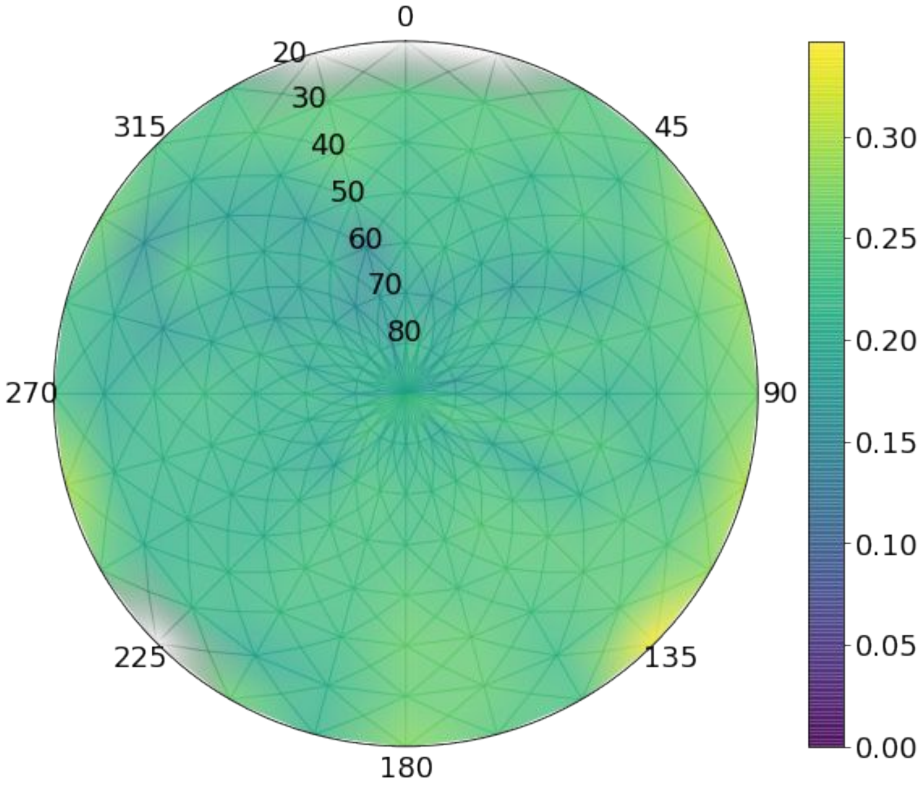
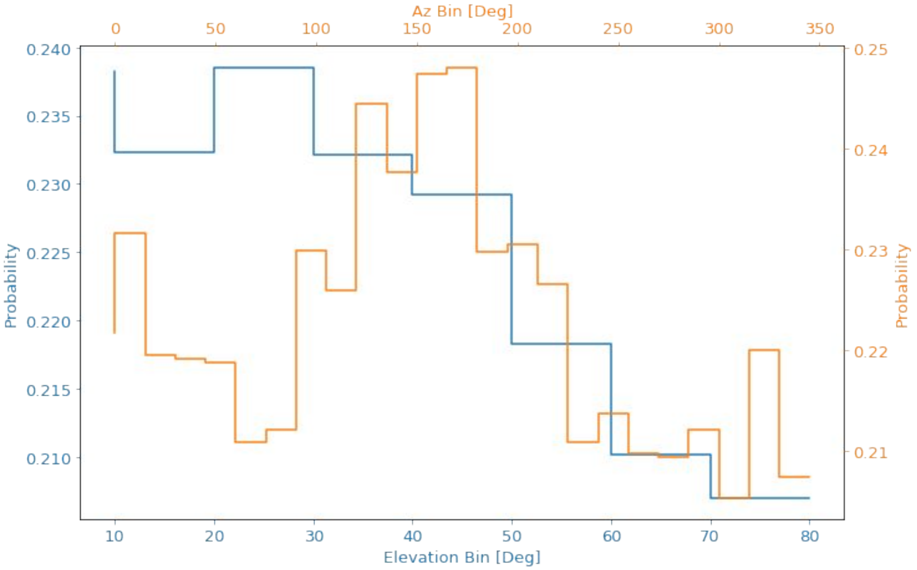
Direction Dependency





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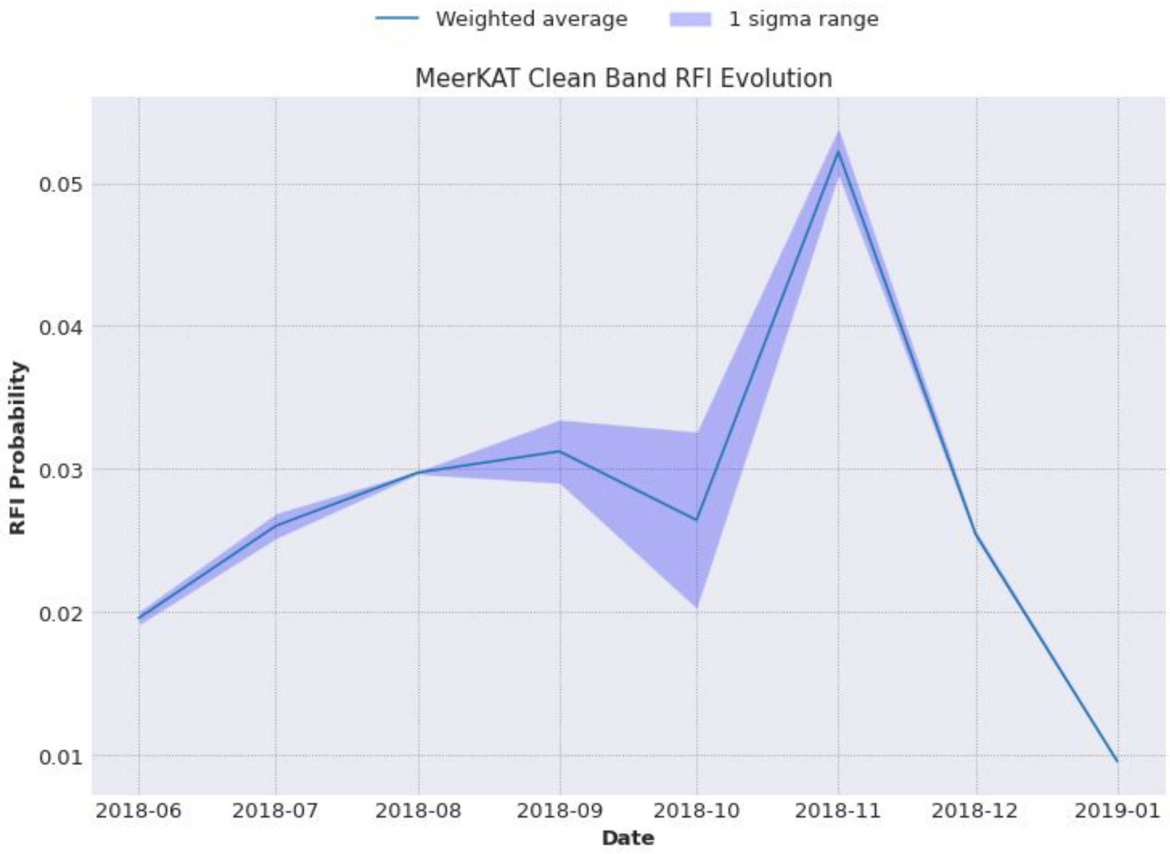
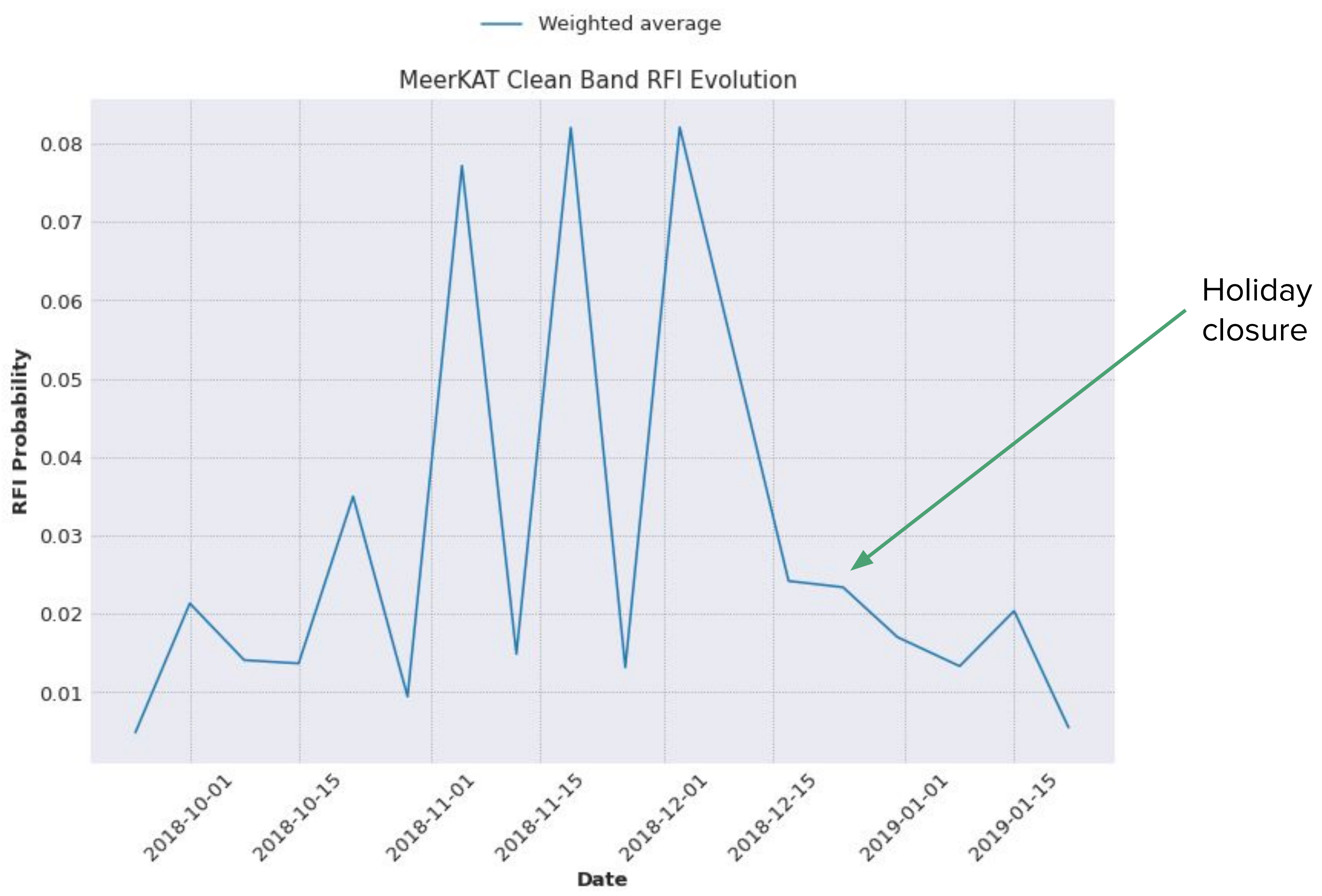
RFI Evolution in the Clean-Band



$$W = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}$$

$$SD = \sqrt{\frac{\sum_{i=1}^{N} w_i (x_i - \bar{x}^*)^2}{\frac{(M-1)}{M} \sum_{i=1}^{N} w_i}},$$



Weighted average
MeerKAT Clean Band RFI Evolution
RFI Probability
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
2018-10-01
2018-10-15
2018-11-01
2018-11-15
2018-12-01
2018-12-15
2019-01-01
2019-01-15
Date
Holiday
closure

Conclusion

- We found the allocated Global System for Mobile (GSM) Communications, flight Distance Measuring Equipment (DME), and UHF-TV bands populate the MeerKAT band
- The L-band suffers from DMEs, GSM, and the GPS satellites
- The fraction of L-band flagged data in November 2018 shows a 300% increase
- In the UHF band, we found that the early morning is least impacted by outliers
- Unusual and unexpected events in the `clean’ MeerKAT L-band

Acknowledgements

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