RFI Measurement & Analysis Techniques

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NRF
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South African Radio Astronomy Observatory

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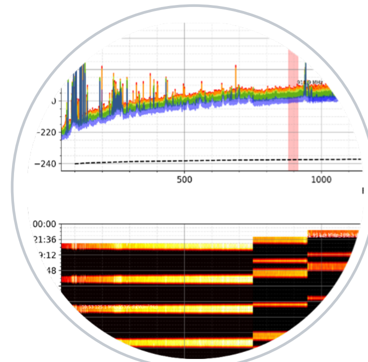
Presentation Overview

RFI Measurement and Analysis Techniques



Introduction

Protection Levels
& Measured Data

Radio Astronomy Protection Levels

ITU-R RA.769
Continuum
Spectral Line

RFI Measurements

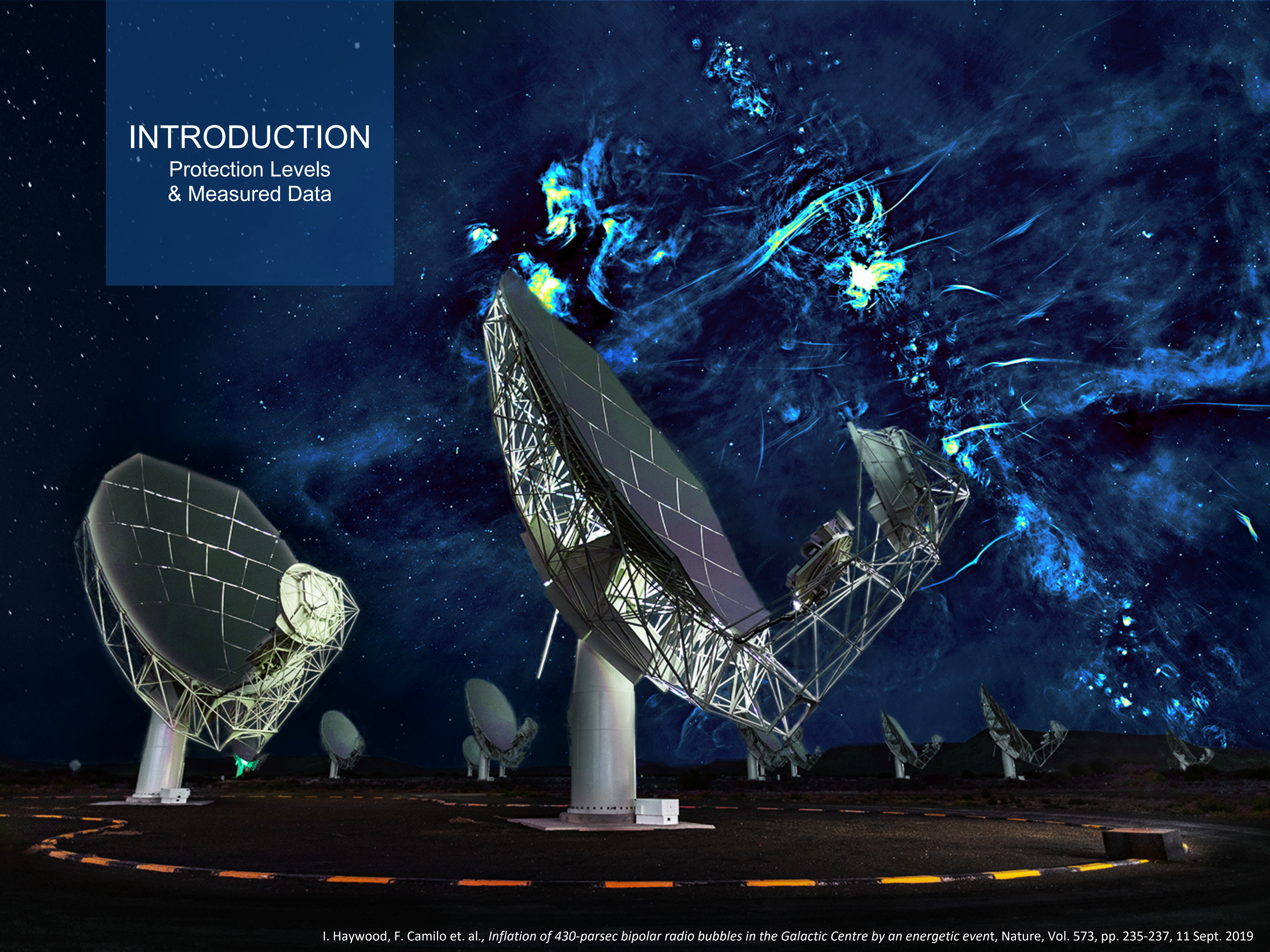
Commercial Standards
Military Standards
SKA Standards

RFI Analysis

Applying Telescope Protection
Levels to Measurements
Bandwidth Compensation

INTRODUCTION

Protection Levels & Measured Data



I. Haywood, F. Camilo et. al., *Inflation of 430-parsec bipolar radio bubbles in the Galactic Centre by an energetic event*, Nature, Vol. 573, pp. 235-237, 11 Sept. 2019

Introduction

Applying Telescope Protection Levels to Measurement Data

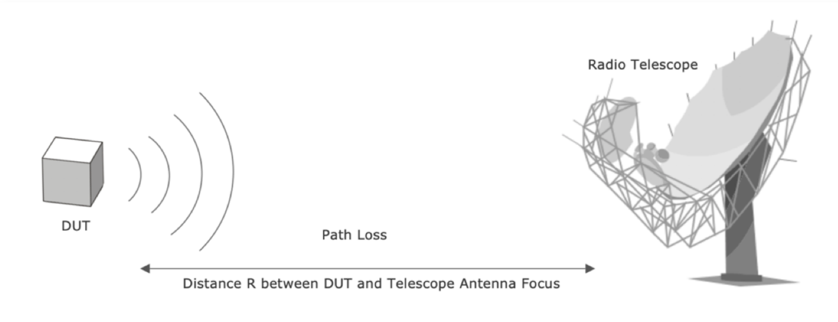
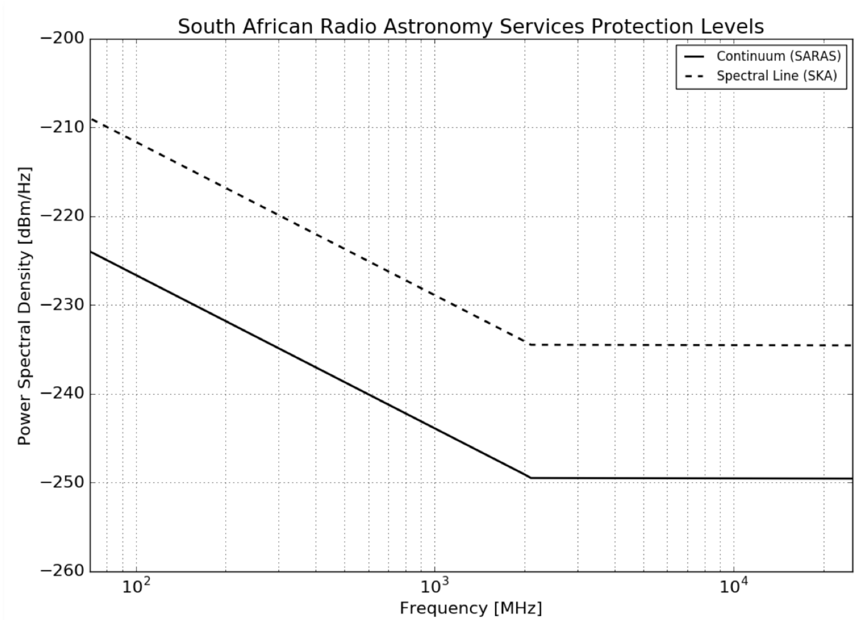


Figure 1: Radiated emissions from DUT equipment toward the radio telescope.

How do you determine if the DUT will impact the radio telescope?



[1] **Astronomy Geographic Advantage Act No. 21 of 2007**
Government Gazette, Vol. 516, No. 31157, Cape Town, Republic of South Africa, 17 June 2008.

[2] **ITU-R RA.769-2**
Recommendation ITU-R RA.769, "*Protection Criteria Used for Radio Astronomical Measurements*", 2003.

[3] **SKA EMI/EMC Standards & Procedures**
P. Dewdney, G.-H. Tan, H. Smith, T. Tzioumis and J. Jonas, *SKA EMI/EMC standards SKA EMI/EMC Standards, Related Procedures and Guidelines*, Document Number SKA-TEL-SKO-0000202, Rev 03, 2017-03-13.

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Introduction

Applying Telescope Protection Levels to Measurement Data

How do you determine if the DUT will impact the radio telescope?

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APPLYING TELESCOPE PROTECTION LEVELS TO MEASUREMENT DATA

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Classification .... Commercial in Confidence
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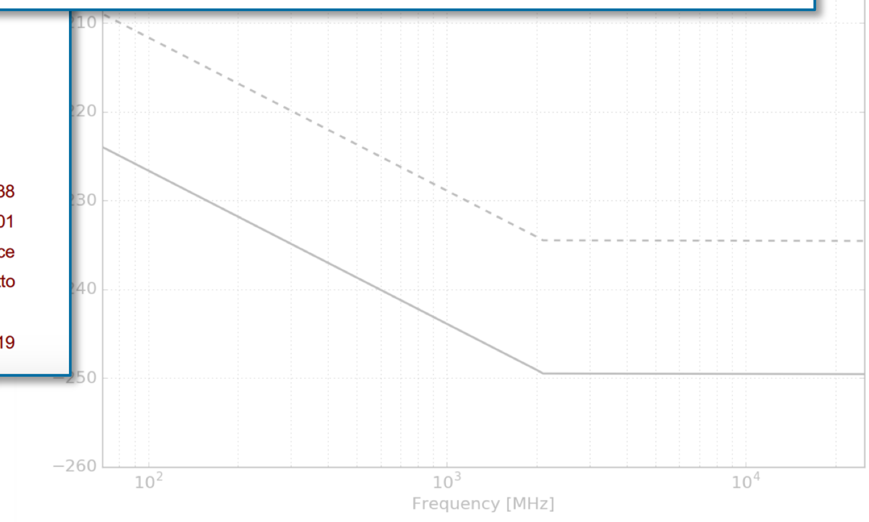
Approval Date .... 12 December 2019

[1] J. Jonas and A. J. Otto, *Applying Telescope Protection Levels to Measurement* Data, Document Number SSA-0008A-038, Revision 1, South African Radio Astronomy Observatory (SARAO), Observatory, Cape Town, South Africa, 12 December 2019.

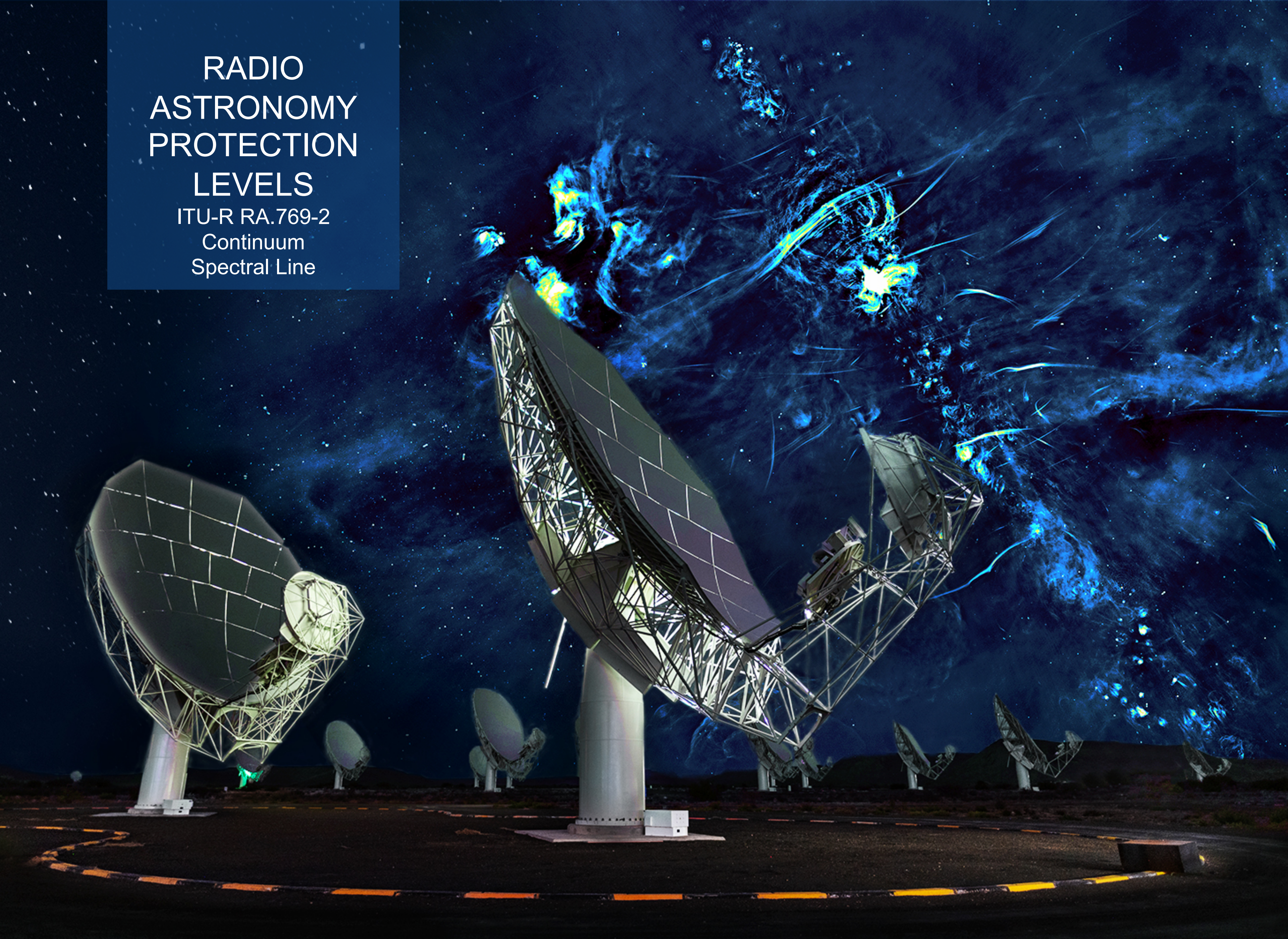


RADIO ASTRONOMY PROTECTION LEVELS

ITU-R RA.769-2

Continuum

Spectral Line



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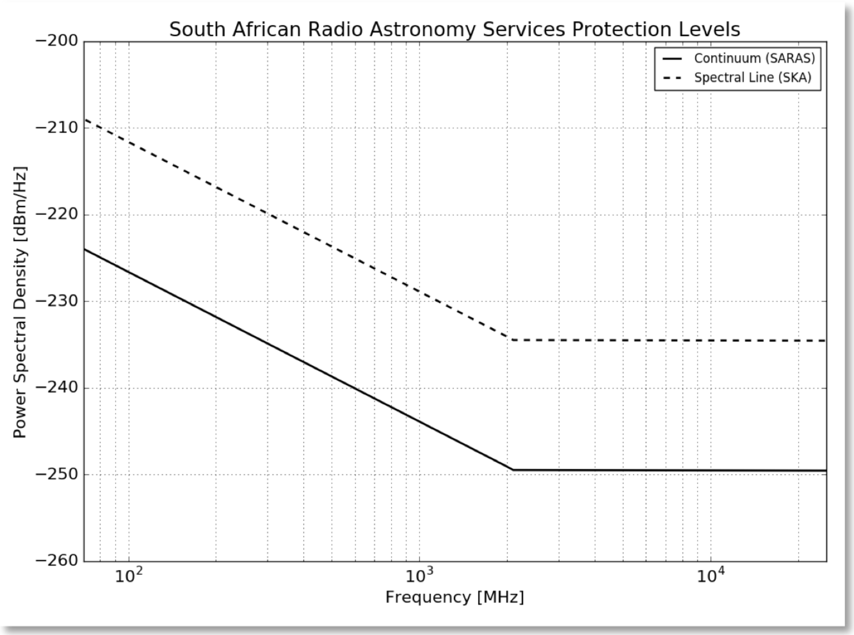
Radio Astronomy Protection Levels

ITU-R RA.769



$$\text{SARAS [dBm/Hz]} = -17.2708\ \log_{10}(f) - 192.0714 \quad \text{for f} < 2\ \text{GHz}$$

$$\text{SARAS [dBm/Hz]} = -0.065676\ \log_{10}(f) - 248.8661 \quad \text{for f} \geq 2\ \text{GHz}$$

- Radio Astronomy Protection Levels for SKA are derived from ITU-R RA.769 which derives thresholds for harmful interference
- Harmful interference defined as interference power, within a chosen BW, that would produce an error of 10% in the smallest power that can be detected by the receiver (based on radiometer equation)
- Integration time of 2000 s with appropriate antenna and receiver noise temperatures

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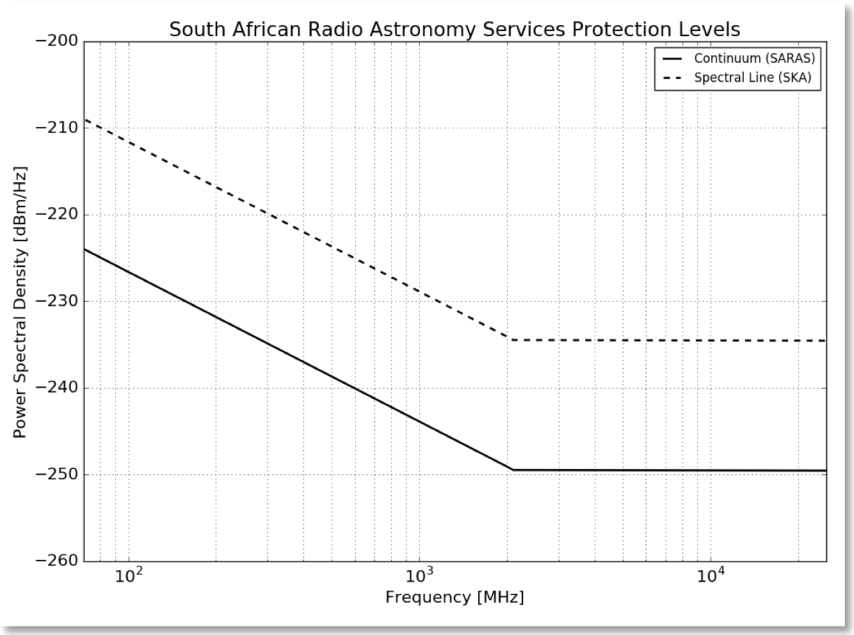
Radio Astronomy Protection Levels

Resolution Bandwidth (#1)



$$\text{SARAS [dBm/Hz]} = -17.2708\ \log_{10}(f) - 192.0714 \quad \text{for f} < 2\text{ GHz}$$

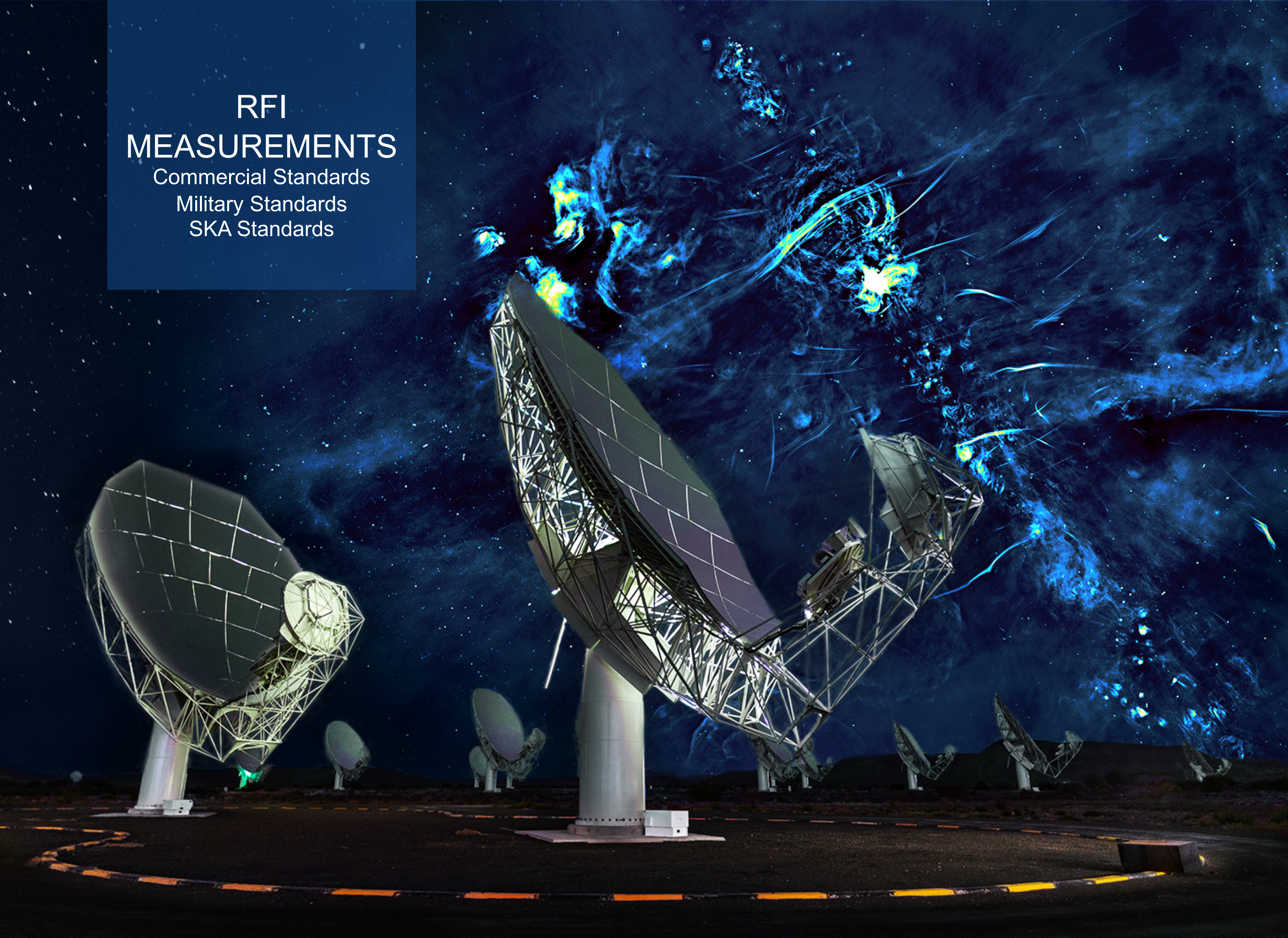
$$\text{SARAS [dBm/Hz]} = -0.065676\ \log_{10}(f) - 248.8661 \quad \text{for f} \geq 2\text{ GHz}$$

- ***Continuum Protection Level:** Resolution Bandwidth equal to 1% of centre frequency being observed
- **Spectral Line Protection Level**: Resolution Bandwidth equal to 0.001% of centre frequency being observed

*In the case of ITU-R RA.769-2, the continuum receiver bandwidth is assumed to be the extent of the ITU primary allocated band for the radio astronomy service. Using a 1% receiver bandwidth is of the same order of magnitude as the ITU allocated bands.

RFI MEASUREMENTS

Commercial Standards
Military Standards
SKA Standards



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RFI Measurements

Commercial Standards

- **Radio Astronomy Protection Levels:**
  Maximum PSD allowed for signal received through 0 dB side lobe or main-lobe as measured at the input to the LNA

- We are often interested in impact of devices not necessarily situated at antenna focus

- Measured levels need to be translated to the focus by some distance R

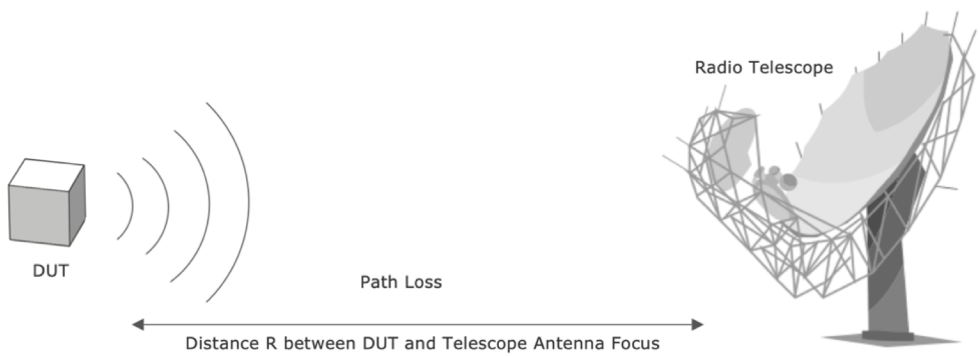


Figure 1: Radiated emissions from DUT equipment toward the radio telescope.

RFI Measurements

Spatial & Temporal Variability

- Given the nature of RFI/EMI both **spatial variability** (extended vs **small culprits) as well as **temporal variability** (continuous vs transient) need to be considered.

  **Small culprits are typically where the DUT is smaller than the antenna beam

- **Spatial Variability**
  - Measurements on Component Level (“small” culprits)
  - Measurements on System Level (”extended” culprits)
- **Temporal Variability**
  - Measurements of Continuous RFI
  - Measurements of EMI
  - Measurements of Transient RFI and EMI

RFI Measurements

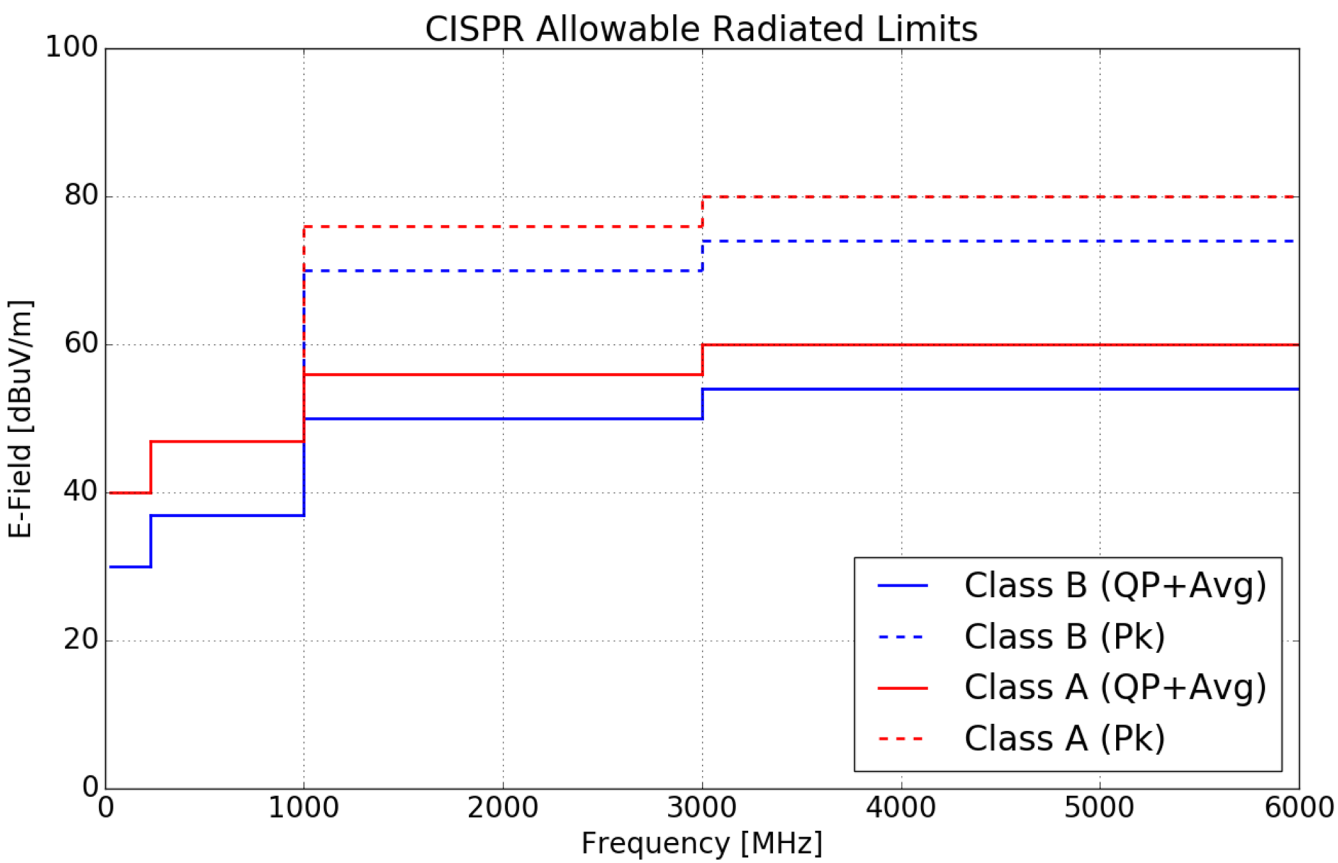
Commercial Standards

- Radiated emissions from **commercial EUT** are typically limited by:
  * Federal Communications Commission (**FCC**) in USA
  * International Special Committee on Radio Interference (**CISPR**) in Europe and South Africa
  * **CISPR** is a committee of the International Electrotechnical Committee (**IEC**)

- Commercial or Military Standards (**MIL-STD**) will typically prescribe:
  1. Resolution Bandwidth
  2. Receiver Detectors
  3. Measurement Distances
  4. Antenna Heights
  5. Allowable Emission Limits
  6. Allowable Susceptibility Limits

RFI Measurements

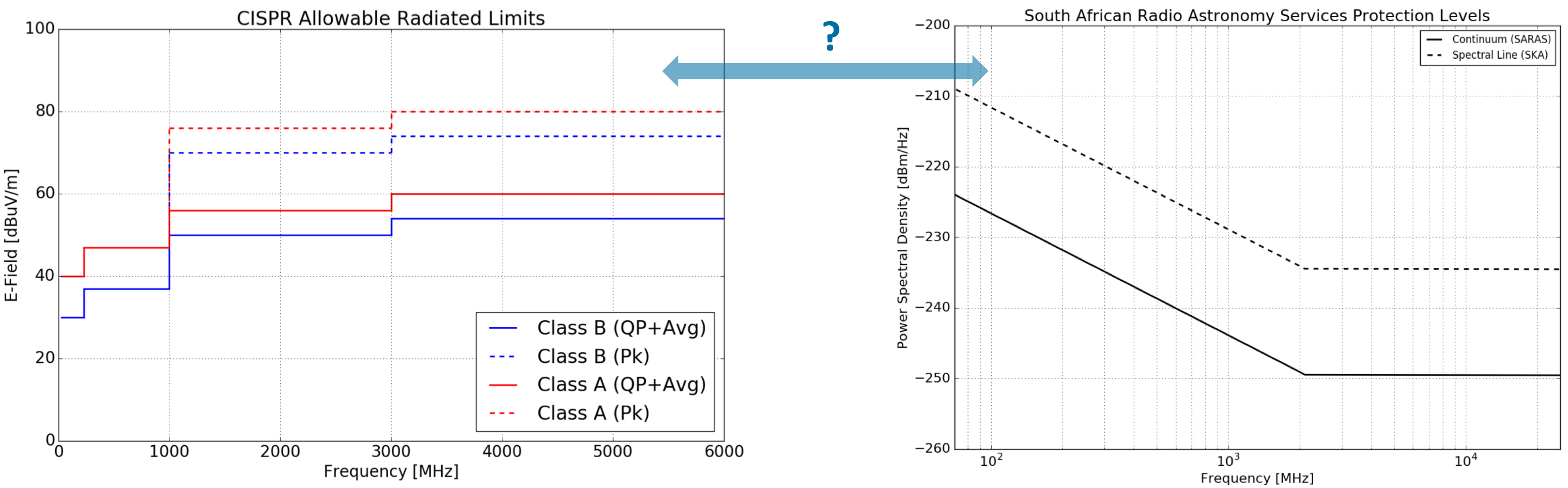
CISPR 11/22 Class A & B



- **9 kHz < f < 30 MHz**
  Conducted Emissions
  RBW = 9 kHz
  QP & Avg. Detector
- **30 MHz < f < 230 MHz**
  Radiated Emissions
  Distance 10 m
  RBW = 120 kHz
  QP Detector
- **230 MHz < f < 1 GHz**
  Radiated Emissions
  Distance 10 m
  RBW = 120 kHz
  QP Detector
- **f > 1 GHz**
  Radiated Emissions
  Distance 3m
  RBW = 1 MHz
  Pk. & Avg. Detectors

RFI Measurements

Resolutions Bandwidth (#2)

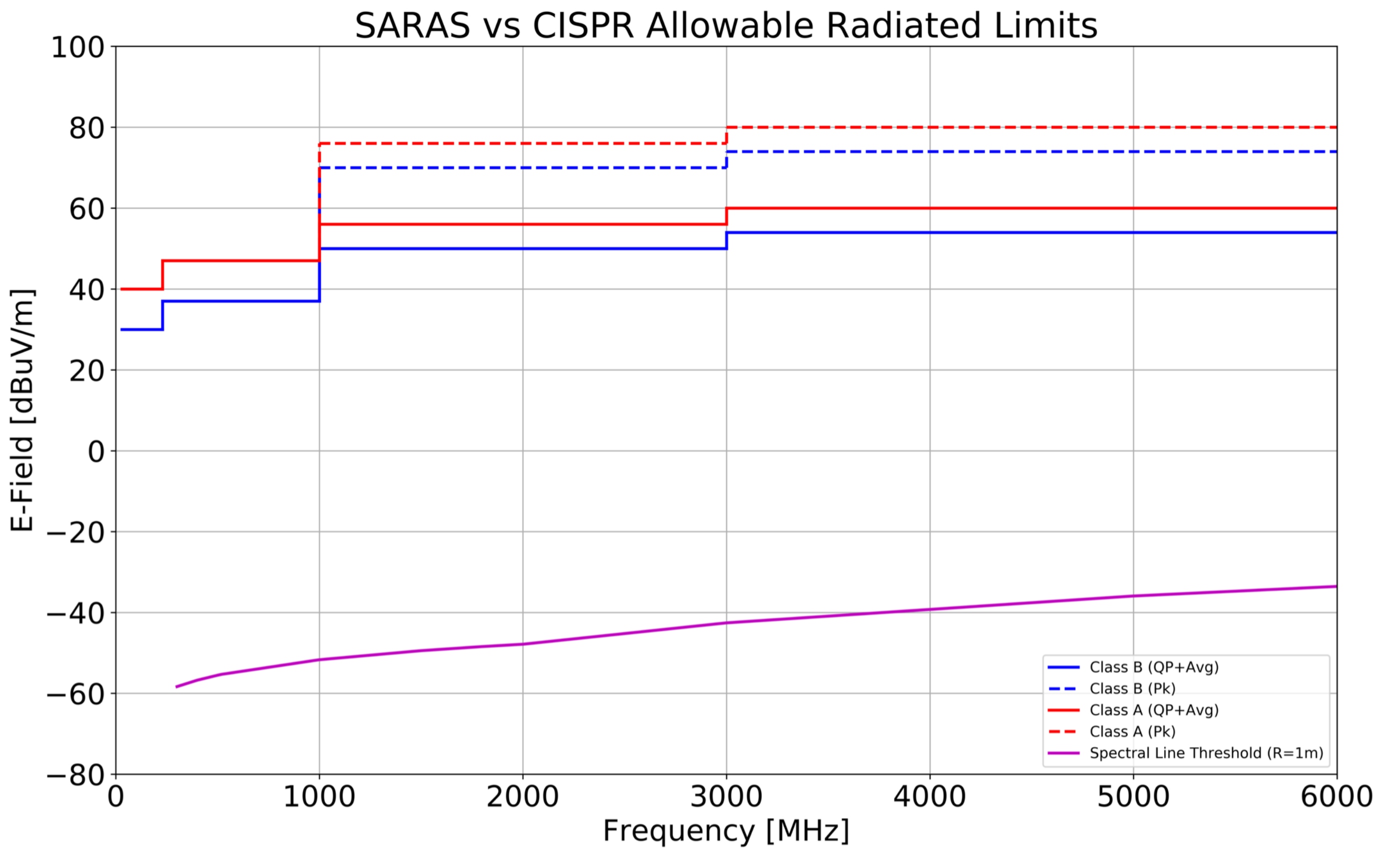


- Electric Field Strength [dBuV/m]
- Constant RBW over Frequency Range (120 kHz or 1 MHz)

- Power Spectral Density [dBm/Hz]
- Continuum: RBW = 1% of fc
- Spectral Line: RBW = 0.001% of fc

RFI Measurements

Resolutions Bandwidth (#2)



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RFI Measurements

Resolutions Bandwidths

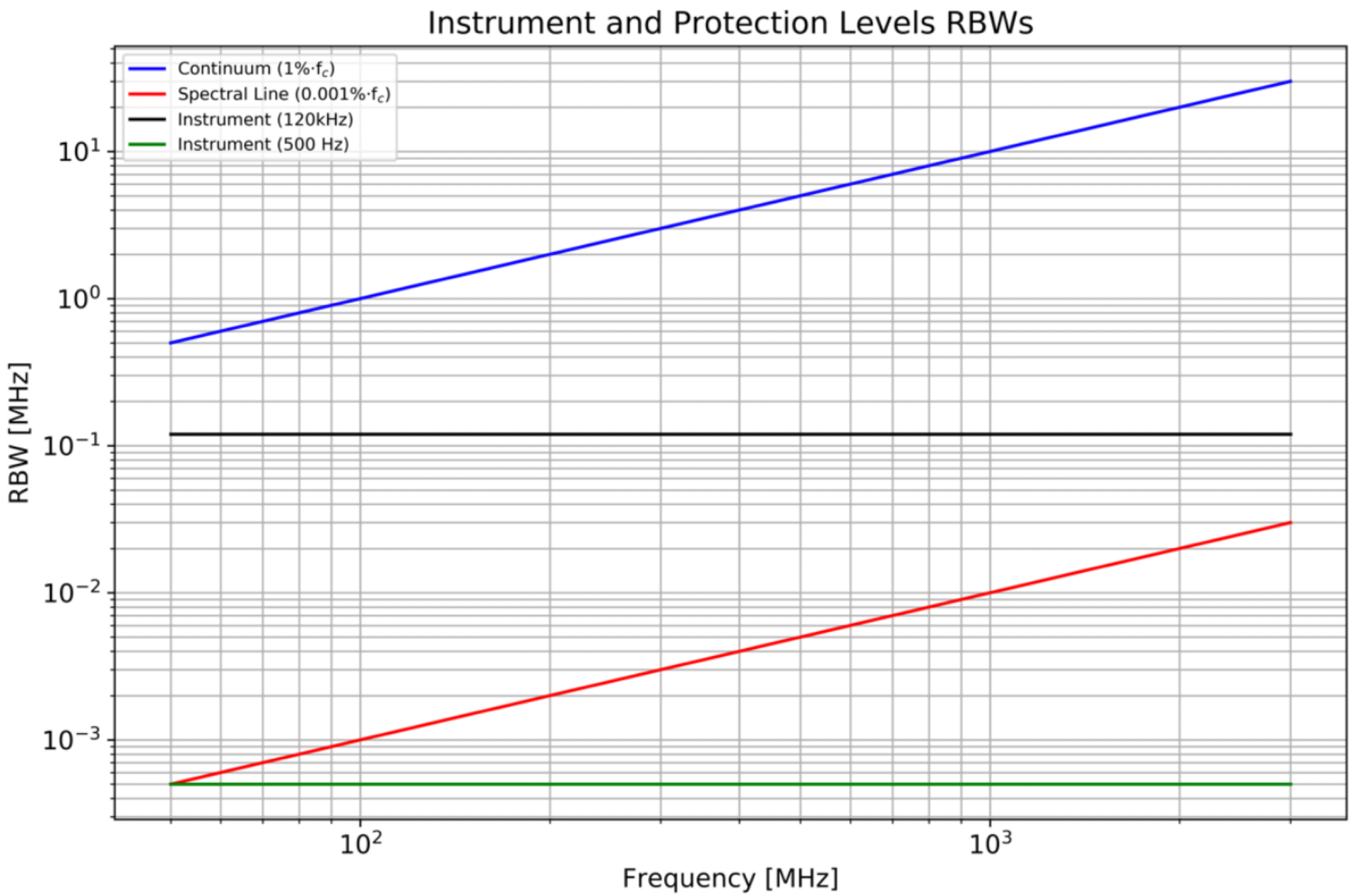
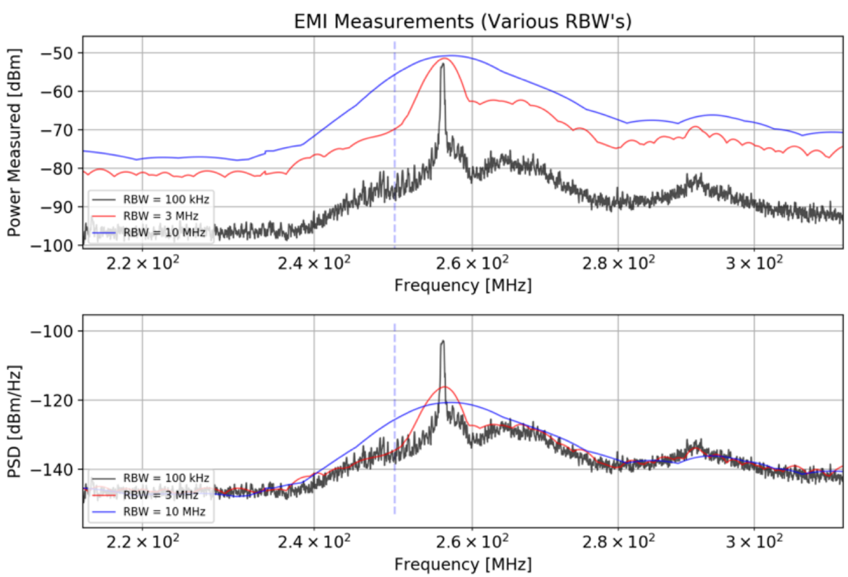


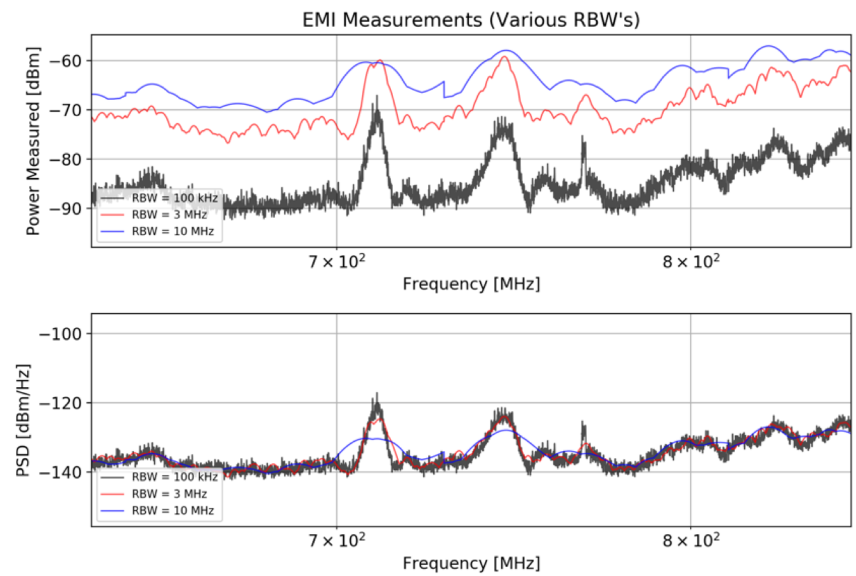
Figure 2: Instrument and Protection Levels Resolution Bandwidths

RFI Measurements

RFI Signal Characteristics :: Resolution Bandwidth (#3)

- Narrowband vs. Wideband signals
- It will always be ideal to match your measurement bandwidth to that of the signal bandwidth





RFI Measurements

Resolution Bandwidths

When characterising emissions from a DUT and determining the impact on a radio telescope receiver, the following bandwidths need to be considered:

1. Interference signal bandwidths: Δf_{sig}
   (for example a narrowband or wideband interference signal)

2. Measurement receiver bandwidths: Δf_{meas}
   (for example using a spectrum analyser with an RBW of 120 kHz as per CISPR 22 Class B, or RTA-3.6 channel width of 25 kHz)

3. Radio astronomy protection levels bandwidths: $\Delta f_{\mathrm{thresh}}$
   (1% or 0.001% of the centre frequency for Continuum or Spectral Line observations respectively)

RFI Measurements

Bandwidth Compensation Factor

$$\eta = \frac{\min\left(\frac{\Delta f_{\mathrm{sig}}}{\Delta f_{\mathrm{meas}}}, 1\right)}{\min\left(\frac{\Delta f_{\mathrm{sig}}}{\Delta f_{\mathrm{thresh}}}, 1\right)}$$

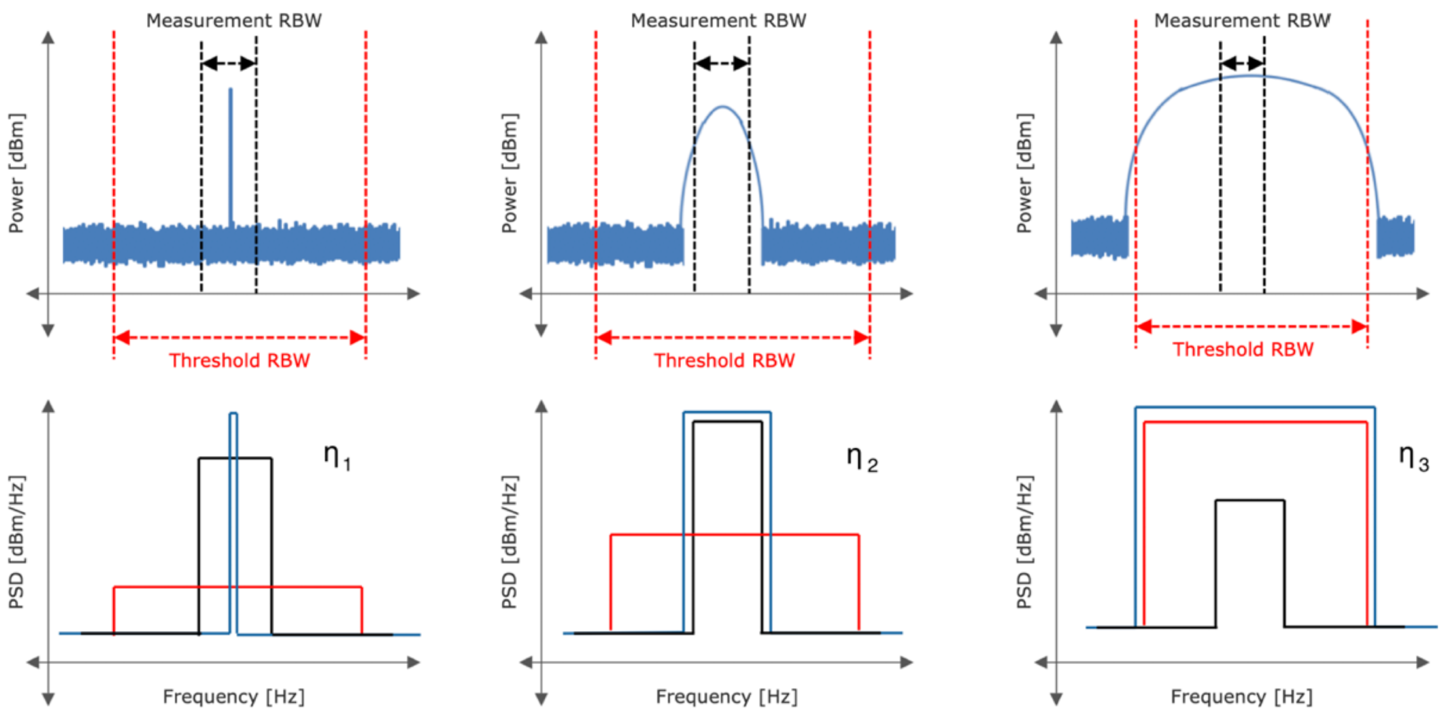
	$\Delta f_{\mathrm{meas}} < \Delta f_{\mathrm{thresh}}$			$\Delta f_{\mathrm{meas}} > \Delta f_{\mathrm{thresh}}$	
Narrowband Signal $\Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{meas}}$	$\eta_1 > 1$	$\Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{thresh}}$	Narrowband Signal $\Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{thresh}}$	$\eta_4 < 1$	$\Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{thresh}}$
$\Delta f_{\mathrm{meas}} \leq \Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{thresh}}$	$\eta_2 > 1$	$\Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{thresh}}$	$\Delta f_{\mathrm{thresh}} \leq \Delta f_{\mathrm{sig}} < \Delta f_{\mathrm{meas}}$	$\eta_5 < 1$	$\Delta f_{\mathrm{sig}} \geq \Delta f_{\mathrm{thresh}}$
Wideband Signal $\Delta f_{\mathrm{sig}} \geq \Delta f_{\mathrm{thresh}}$	$\eta_3 = 1$	$\Delta f_{\mathrm{sig}} \geq \Delta f_{\mathrm{meas}}$	Wideband Signal $\Delta f_{\mathrm{sig}} \geq \Delta f_{\mathrm{meas}}$	$\eta_6 = 1$	$\Delta f_{\mathrm{sig}} \geq \Delta f_{\mathrm{thresh}}$

Table 1: Various combinations of signal, instrument and protection level bandwidths will result in a different bandwidth compensation factor (η).

RFI Measurements

Bandwidth Compensation Factor :: $\Delta f_{meas} < \Delta f_{thresh}$

$\Delta f_{meas} < \Delta f_{thresh}$



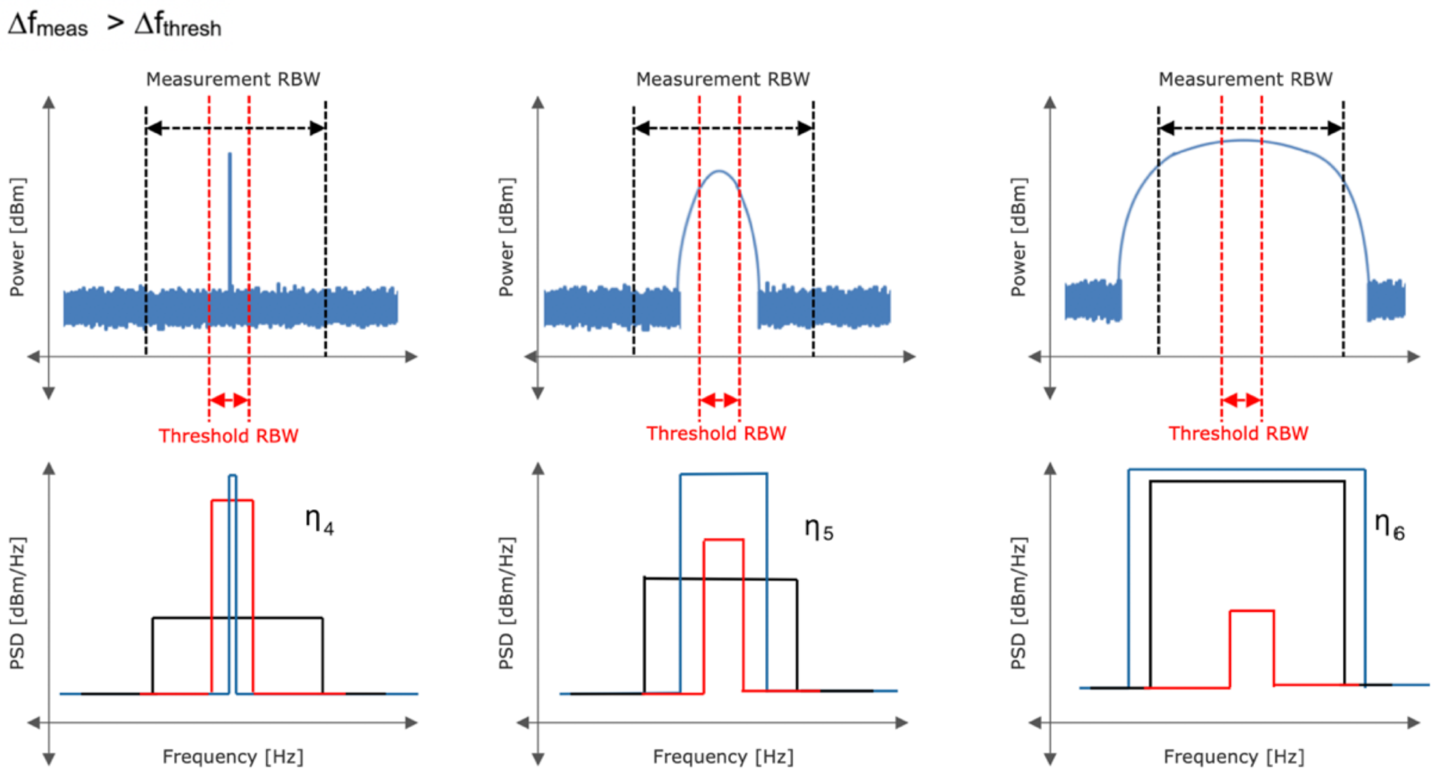
$$\eta_1 = \frac{\Delta f_{\text{thresh}}}{\Delta f_{\text{meas}}} > 1$$

$$\eta_2 = \frac{\Delta f_{\text{thresh}}}{\Delta f_{\text{sig}}} > 1$$

$$\eta_3 = 1$$

RFI Measurements

Bandwidth Compensation Factor :: $\Delta f_{meas} > \Delta f_{thresh}$



$$\eta_4 = \frac{\Delta f_{\text{thresh}}}{\Delta f_{\text{meas}}} < 1$$

$$\eta_5 = \frac{\Delta f_{\text{sig}}}{\Delta f_{\text{meas}}} < 1$$

$$\eta_6 = 1$$

Bandwidth Compensation Factor

Mathematical Derivation

If a signal is band-limited and assumed to have a rectangular power spectral density $PSD_{sig}(f)$ centered on a frequency f_0, then its PSD is:

$$PSD_{sig}(f) = \begin{cases} \dfrac{P_{sig}}{\Delta f_{sig}} & f_0 - \dfrac{\Delta f_{sig}}{2} \leq f \leq f_0 + \dfrac{\Delta f_{sig}}{2} \quad [\text{dBm/Hz}] \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

When making a measurement of the spectrum of a signal, the power value (P_{meas}) recorded at a frequency sample f_0 is equal to the integral of the *intrinsic* signal power spectral density ($PSD_{sig}(f)$) multiplied by the channel bandpass response ($|H(f)|^2$):

$$P_{meas}(f_0) = \int_{-\infty}^{+\infty} |H(f)|^2 \cdot PSD_{sig}(f + f_0) \cdot df \quad [\text{W}] \tag{2}$$

This equation can be considered to be the convolution of the signal PSD_{sig} with the bandpass response of the measuring device. Approximating the bandpass response to be rectangular, this can be simplified to:

$$P_{meas}(f_0) \approx \int_{f_0 - \frac{\Delta f_{meas}}{2}}^{f_0 + \frac{\Delta f_{meas}}{2}} PSD_{sig}(f) \cdot df \quad [\text{W}] \tag{3}$$

Bandwidth Compensation Factor

Mathematical Derivation

Combining equations (1) and (3):

$$P_{\text{meas}}(f_0) \approx \begin{cases} \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{sig}}}{2}}^{f_0+\frac{\Delta f_{\text{sig}}}{2}} df = P_{\text{sig}} & \Delta f_{\text{sig}} \leq \Delta f_{\text{meas}} \\ \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{meas}}}{2}}^{f_0+\frac{\Delta f_{\text{meas}}}{2}} df = \left(\dfrac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) \cdot P_{\text{sig}} \quad (<P_{sig}) & \Delta f_{\text{sig}} > \Delta f_{\text{meas}} \end{cases} \tag{5}$$

which can be simplified to:

$$P_{\text{meas}}(f_0) \approx \min\left(1, \frac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) P_{\text{sig}} \quad [\text{W}] \tag{6}$$

Bandwidth Compensation Factor

Mathematical Derivation

Combining equations (1) and (3):

$$P_{\text{meas}}(f_0) \approx \begin{cases} \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{sig}}}{2}}^{f_0+\frac{\Delta f_{\text{sig}}}{2}} df = P_{\text{sig}} & \Delta f_{\text{sig}} \leq \Delta f_{\text{meas}} \\ \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{meas}}}{2}}^{f_0+\frac{\Delta f_{\text{meas}}}{2}} df = \left(\dfrac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) \cdot P_{\text{sig}} \quad (<P_{sig}) & \Delta f_{\text{sig}} > \Delta f_{\text{meas}} \end{cases} \tag{5}$$

which can be simplified to:

$$P_{\text{meas}}(f_0) \approx \min\left(1, \frac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) P_{\text{sig}} \quad [\text{W}] \tag{6}$$

If the channel bandwidth of the measuring instrument is wider than the *intrinsic* signal bandwidth then the measured power at sample frequency f_0 is equal to the total power of the signal, and independent of the channel bandwidth. Conversely, if the channel bandwidth of the measuring instrument is narrower than the *intrinsic* signal bandwidth then the measured power at sample frequency f_0 is diluted by a factor of $\Delta f_{meas}/\Delta f_{sig}$ relative to the total signal power. If the total signal power is required then the power contributions from an appropriate number of adjacent channels need to be summed.

Bandwidth Compensation Factor

Mathematical Derivation

Combining equations (1) and (3):

$$P_{\text{meas}}(f_0) \approx \begin{cases} \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{sig}}}{2}}^{f_0+\frac{\Delta f_{\text{sig}}}{2}} df = P_{\text{sig}} & \Delta f_{\text{sig}} \leq \Delta f_{\text{meas}} \\ \dfrac{P_{\text{sig}}}{\Delta f_{\text{sig}}} \displaystyle\int_{f_0-\frac{\Delta f_{\text{meas}}}{2}}^{f_0+\frac{\Delta f_{\text{meas}}}{2}} df = \left(\dfrac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) \cdot P_{\text{sig}} \quad (< P_{sig}) & \Delta f_{\text{sig}} > \Delta f_{\text{meas}} \end{cases} \tag{5}$$

which can be simplified to:

$$P_{\text{meas}}(f_0) \approx \min\left(1, \frac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) P_{\text{sig}} \quad [\text{W}] \tag{6}$$

If the channel bandwidth of the measuring instrument is wider than the *intrinsic* signal bandwidth then the measured power at sample frequency f_0 is equal to the total power of the signal, and independent of the channel bandwidth. Conversely, if the channel bandwidth of the measuring instrument is narrower than the *intrinsic* signal bandwidth then the measured power at sample frequency f_0 is diluted by a factor of $\Delta f_{meas}/\Delta f_{sig}$ relative to the total signal power. If the total signal power is required then the power contributions from an appropriate number of adjacent channels need to be summed.

Bandwidth Compensation Factor

Mathematical Derivation

$$P_N = k\, T_{sys}\, \Delta f_{meas}$$

$$\sigma = \frac{k\, T_{sys}\, \Delta f_{meas}}{\sqrt{\Delta f_{meas}\, t_i}}$$

The noise floor of the measurement device is proportional to the measurement bandwidth (RBW for a spectrum analyzer), and the statistical fluctuations of the noise floor are proportional to the square-root of the measurement bandwidth. Using this information together with equation (6), the signal-to-noise ratio (SNR) for the measurement of a signal spectrum has this dependence on the measurement bandwidth:

$$\mathrm{SNR} \propto \frac{\min\left(1, \frac{\Delta f_{\mathrm{meas}}}{\Delta f_{\mathrm{sig}}}\right)}{\sqrt{\Delta f_{\mathrm{meas}}}} = \begin{cases} \sqrt{\Delta f_{\mathrm{meas}}}/\Delta f_{\mathrm{sig}} & \left(<1/\sqrt{\Delta f_{\mathrm{sig}}}\right) \quad \Delta f_{\mathrm{meas}} < \Delta f_{\mathrm{sig}} \\ 1/\sqrt{\Delta f_{\mathrm{sig}}} & \quad \Delta f_{\mathrm{meas}} = \Delta f_{\mathrm{sig}} \\ 1/\sqrt{\Delta f_{\mathrm{meas}}} & \left(<1/\sqrt{\Delta f_{\mathrm{sig}}}\right) \quad \Delta f_{\mathrm{meas}} > \Delta f_{\mathrm{sig}} \end{cases} \qquad (7)$$

The SNR for the transition case where $\Delta f_{\mathrm{meas}} = \Delta f_{\mathrm{sig}}$, i.e. when the measurement bandwidth if *matched* to the signal bandwidth. This is **always** the optimal measurement configuration for detecting spectral line components of signals and measuring their power or PSD.

Bandwidth Compensation Factor

Mathematical Derivation

The *measured* PSD is defined to be:

$$PSD_{\text{meas}}(f_0) = \frac{P_{\text{meas}}(f_0)}{\Delta f_{\text{meas}}} \quad [\text{W/Hz}] \tag{8}$$

which when combined with equation (6) results in:

$$PSD_{\text{meas}}(f_0) \approx \frac{\min\left(1, \frac{\Delta f_{\text{meas}}}{\Delta f_{\text{sig}}}\right) P_{\text{sig}}}{\Delta f_{\text{meas}}} \quad [\text{W/Hz}] \tag{9}$$

Multiplying the numerator and denominator by $\Delta f_{sig}/\Delta f_{meas}$:

$$PSD_{\text{meas}}(f_0) \approx \frac{\min\left(\frac{\Delta f_{\text{sig}}}{\Delta f_{\text{meas}}}, 1\right) P_{\text{sig}}}{\Delta f_{\text{sig}}} = \min\left(\frac{\Delta f_{\text{sig}}}{\Delta f_{\text{meas}}}, 1\right) PSD_{\text{sig}} \quad [\text{W/Hz}] \tag{10}$$

If $\Delta f_{meas} < \Delta f_{sig}$ then the *intrinsic* spectrum is *resolved* and the measured PSD is equal to the intrinsic signal PSD. Conversely, when $\Delta f_{meas} > \Delta f_{sig}$ the spectrum is smeared out by the convolution with the channel bandpass response, and is diluted by a factor $\Delta f_{sig}/\Delta f_{meas}$. Unless the intrinsic signal is known, it is not possible to estimate the intrinsic signal PSD from the measured spectrum.

Bandwidth Compensation Factor

Mathematical Derivation

The SKA and SARAS RFI regulations specify signal spectral density thresholds to be met for particular channel bandwidths, specified as fractional bandwidths about a given centre frequency, i.e. $\Delta f_{thresh} = 0.01f_0$ for the Continuum threshold and $\Delta f_{thresh} = 0.00001f_0$ for the Spectral Line threshold. It is not always practical or possible (or even desirable if the measurement SNR is to be optimised) to measure the RFI signal PSD at the specified channel bandwidth, so it is necessary to understand the relationship between the PSD determined using a channel bandwidth of Δf_{meas} and the compliance PSD defined using a specified bandwidth of Δf_{thresh}. Equation (10) can be recast in terms of the required channel bandwidth associated with the RFI threshold:

$$PSD_{\text{thresh}}(f_0) \approx \min\left(\frac{\Delta f_{\text{sig}}}{\Delta f_{\text{thresh}}}, 1\right) PSD_{\text{sig}} \quad [\text{W/Hz}] \tag{11}$$

Bandwidth Compensation Factor

Mathematical Derivation

When comparing the measured PSD in equation (10) to the threshold PSD in equation (11):

$$PSD_{\text{meas}}(f_0) \approx \eta \times PSD_{\text{thresh}}(f_0) \tag{12}$$

where the scaling factor is referred to as the bandwidth compensation factor (η):

$$\eta = \frac{\min\left(\frac{\Delta f_{\text{sig}}}{\Delta f_{\text{meas}}}, 1\right)}{\min\left(\frac{\Delta f_{\text{sig}}}{\Delta f_{\text{thresh}}}, 1\right)} \tag{13}$$

Bandwidth Compensation Factor

Mathematical Derivation

In [9] it is shown that an alternative to scaling and/or smoothing the measured PSDs for comparison with threshold levels would be to **compare the measured PSD against two threshold levels**: the **original threshold level** and a **scaled level that compensates for the bandwidth effects**, i.e.

$$\boxed{\mathrm{PSD}_{\mathrm{comp}} = \mathrm{PSD}_{\mathrm{thresh}} \times \left(\frac{\Delta f_{\mathrm{thresh}}}{\Delta f_{\mathrm{meas}}}\right)} \qquad (14)$$

Measured signal spectrum components that are **lower** than the **more conservative** threshold level is an **uncontested compliance**, and signal components that **exceed** the **more lenient** threshold level is an **uncontested non-compliance**.

Signal components that fall between the two threshold levels could be examined on a case-by-case basis, taking the measured or *a priori* signal bandwidth into account when making a compliance judgement.

Measurement Case Study

EMI Measurements

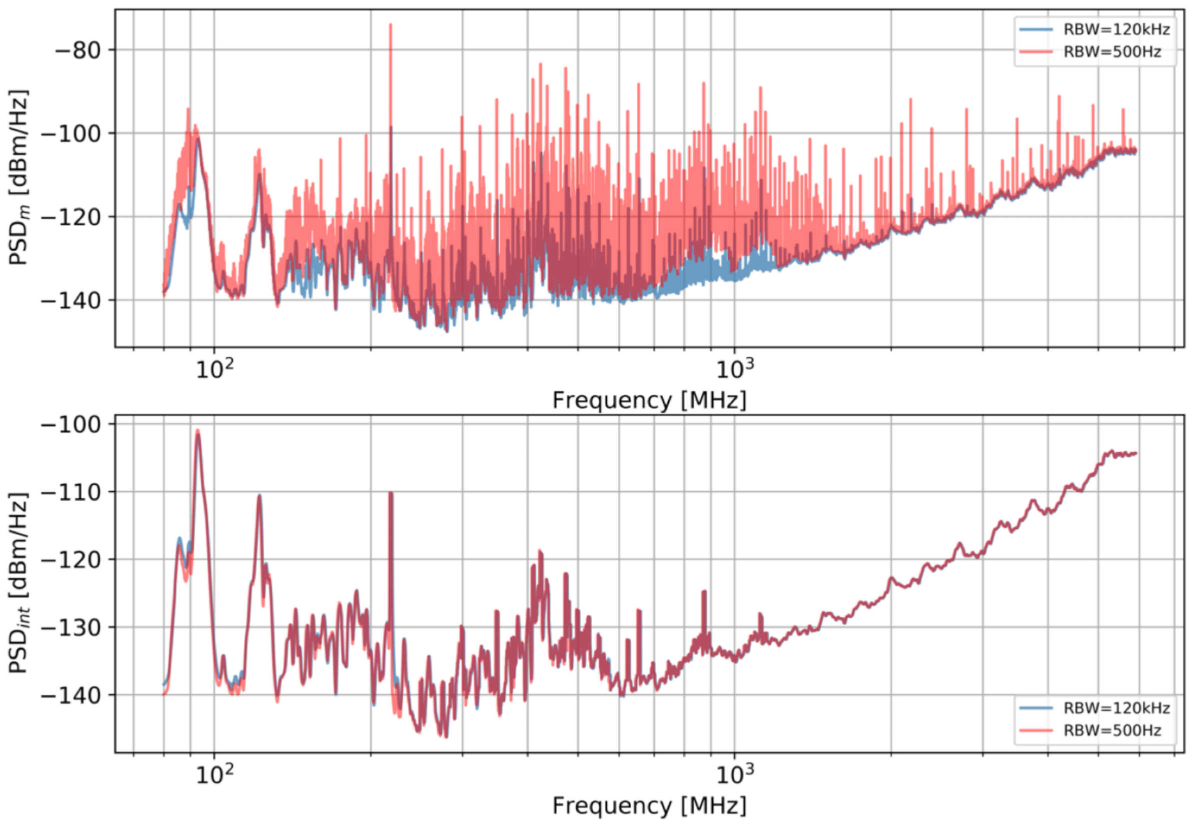
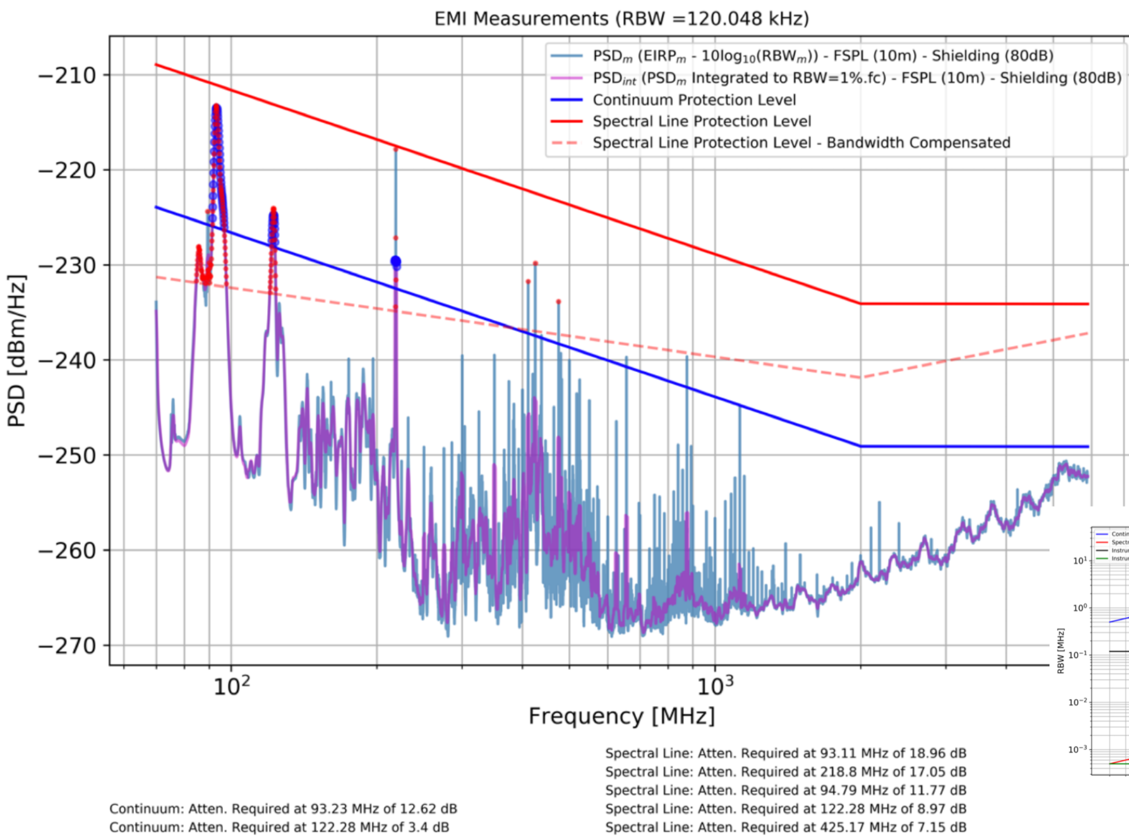


Figure 4: (Top) Measured PSD for RBW=120 kHz (blue trace) and RBW = 500 Hz (red trace);
(Bottom) Integrated PSD to equivalent Continuum RBW = 1%·f_c

Measurement Case Study

EMI Measurements



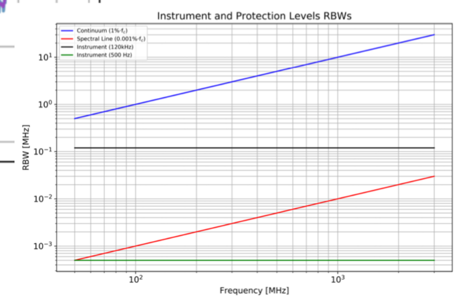
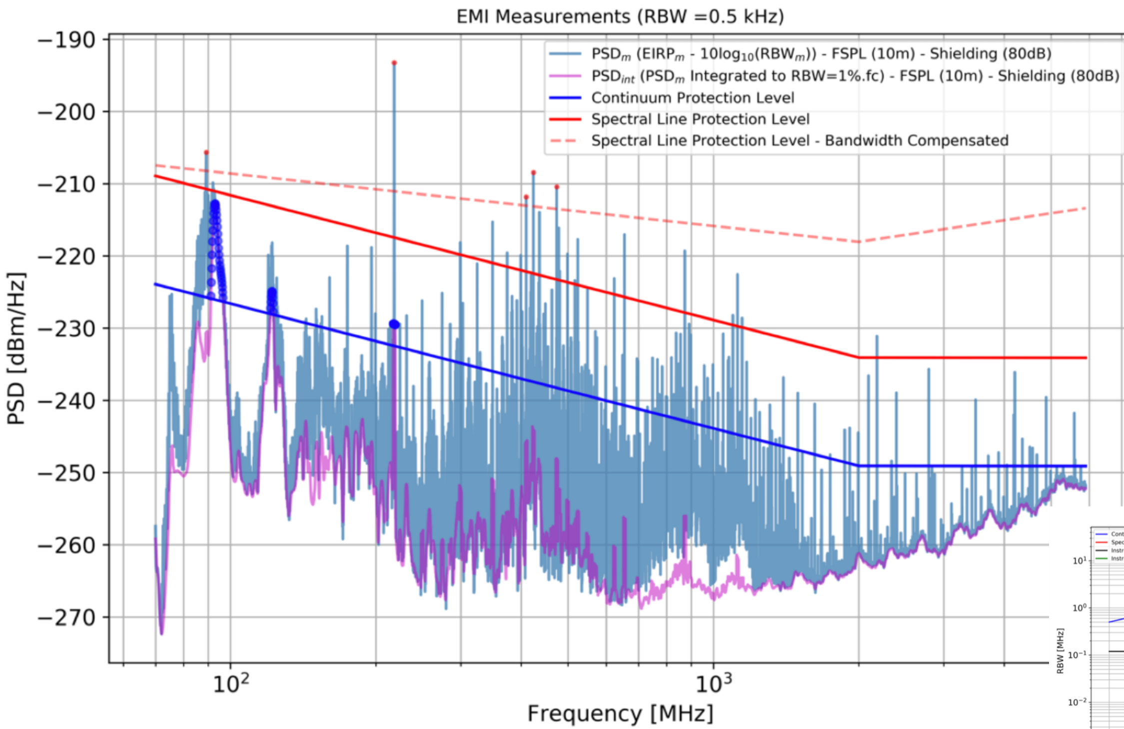


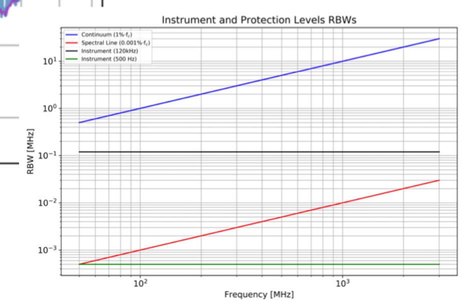
Figure 2: Instrument and Protection Levels Resolution Bandwidths

Figure 5: Measured PSD (light blue trace) with RBW = 120 kHz and Integrated PSD (magenta trace) for a DUT at R = 10m from the receiver in a shielded enclosure of 80 dB compared to Continuum and Bandwidth Compensated Spectral Line Thresholds.

Measurement Case Study

EMI Measurements





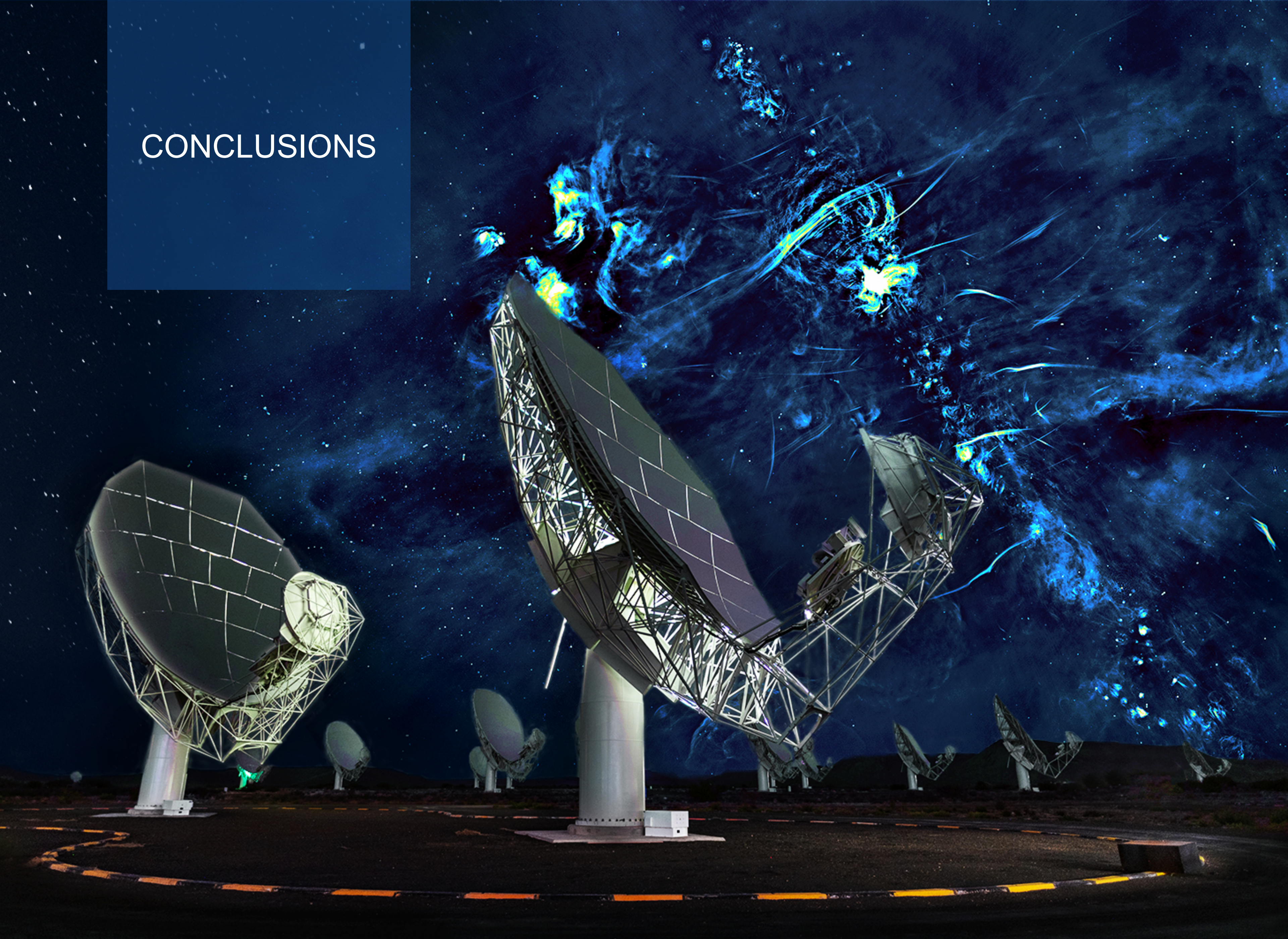
Continuum: Atten. Required at 92.9 MHz of 13.3 dB
Continuum: Atten. Required at 122.02 MHz of 3.2 dB

Spectral Line: Atten. Required at 218.3 MHz of 17.83 dB
Spectral Line: Atten. Required at 423.97 MHz of 4.71 dB

Figure 2: Instrument and Protection Levels Resolution Bandwidths

Figure 6: Measured PSD (light blue trace) with RBW = 500 Hz and Integrated PSD (magenta trace) for a DUT at R = 10m from the receiver in a shielded enclosure of 80 dB compared to Continuum and Bandwidth Compensated Spectral Line Thresholds.

CONCLUSIONS



I. Haywood, F. Camilo et. al., *Inflation of 430-parsec bipolar radio bubbles in the Galactic Centre by an energetic event*, Nature, Vol. 573, pp. 235-237, 11 Sept. 2019

Conclusions

When characterising emissions from a DUT and determining the impact on a radio telescope receiver, the following bandwidths need to be considered:

a. Interference signal bandwidths: Δf_{sig}
   (for example a narrowband or wideband interference signal)

b. Measurement receiver bandwidths: Δf_{meas}
   (for example using a spectrum analyser with an RBW of 120 kHz as per CISPR 22 Class B, or RTA-3.6 channel width of 25 kHz)

c. Radio astronomy protection levels bandwidths: $\Delta f_{\mathrm{thresh}}$
   (1% or 0.001% of the centre frequency for Continuum or Spectral Line observations respectively)

$$\eta = \frac{\min\left(\frac{\Delta f_{\mathrm{sig}}}{\Delta f_{\mathrm{meas}}}, 1\right)}{\min\left(\frac{\Delta f_{\mathrm{sig}}}{\Delta f_{\mathrm{thresh}}}, 1\right)}$$

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NRF National Research Foundation

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The South African Radio Astronomy Observatory (SARAO) is a National Facility managed by the National Research Foundation and incorporates all national radio astronomy telescopes and programmes. SARAO is responsible for implementing the Square Kilometre Array (SKA) in South Africa.

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