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Netherlands Institute for Radio Astronomy

Radio Quiet Zones for the SKA

and

How to keep things quiet

IUCAF, Fourth School in Spectrum Management for Radio Astronomy

Rob Millenaar

Agenda

On Radio Quiet Zones for the SKA,

but more importantly,

On how to manage the risk of self pollution.

- The SKA in brief
- The sites
- Radio Quiet Zones in Australia and South Africa
- An EMI policy for the SKA
- Summary remarks

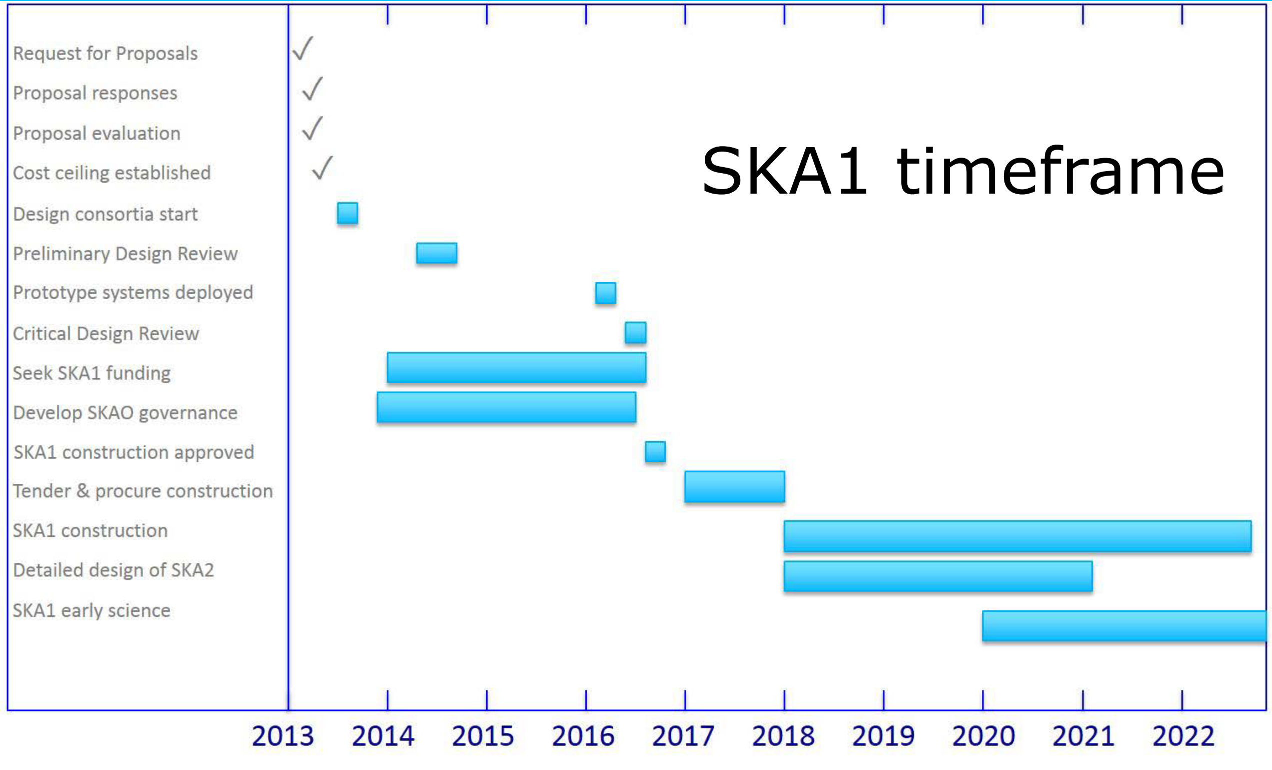
Part 1: The SKA

The SKA in brief

The SKA is the next BIG thing in radio astronomy…

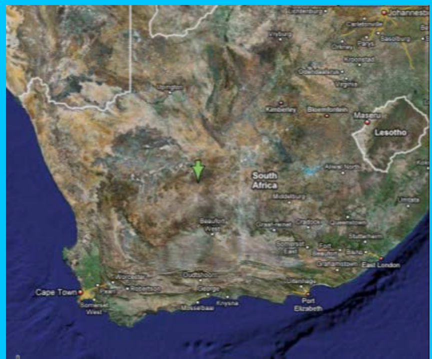
With ultimately (Phase 2):

- Thousands of dishes
- Hundreds of thousands of aperture array antennas and receivers
- Spread over a very large region, up to a few 1000km
- Built by consortia from all over the world
- With unprecedented sensitivity
- With continuous frequency coverage from 50 MHz to >15 GHz.

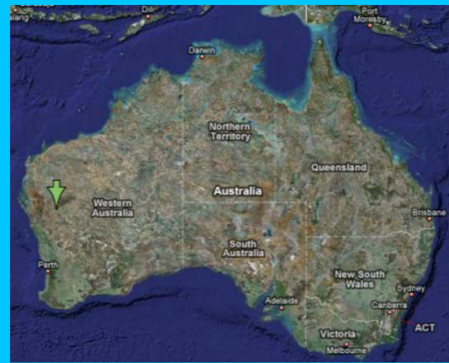


The SKA sites (SKA1)
Cost €650M, construction start 2018

South Africa



Australia



SKA1-MID

254 Dishes including:

64 MeerKAT Dishes

190 SKA Dishes

SKA1-SURVEY

96 Dishes including:

36 ASKAP Dishes

60 SKA Dishes

SKA1-LOW

Low Frequency

Aperture Array

Stations

The SKA sites (SKA2)
Cost TBD, construction start 2022

South Africa

Australia

SKA2-MID
2500 Dishes
(expansion)

SKA2-AA
Mid Frequency
Aperture Array
Stations

SKA2-LOW
Low Frequency
Aperture Array
Stations
(expansion)

Part 2: Quiet Please

The sites and their radio quietness

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- Given the science ambitions and the cost of the SKA, is it of prime importance that the radio frequency environment enables and not hampers this.
- Therefore a long process of site characterisation that included site monitoring has led to the two selected sites.
- These sites are very Radio Quiet… but they are not Radio Silent. So there will always be radio interference to deal with.
- One element considered during the site selection process was the way a **Radio Quiet Zone** protecting the core site can be established.
- Both sites have elaborate legislation for a RQZ established or in progress.

Radio Quiet Zones
some aspects

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A general overview of Radio Quiet Zones was presented by Carol Wilson at the 2010 IUCAF SMSS in Japan; download here:

http://www.iucaf.org/SSS2010/presentations/day5/Wilson(RQZ).ppt

Methods to help establishing radio quiet reserves:

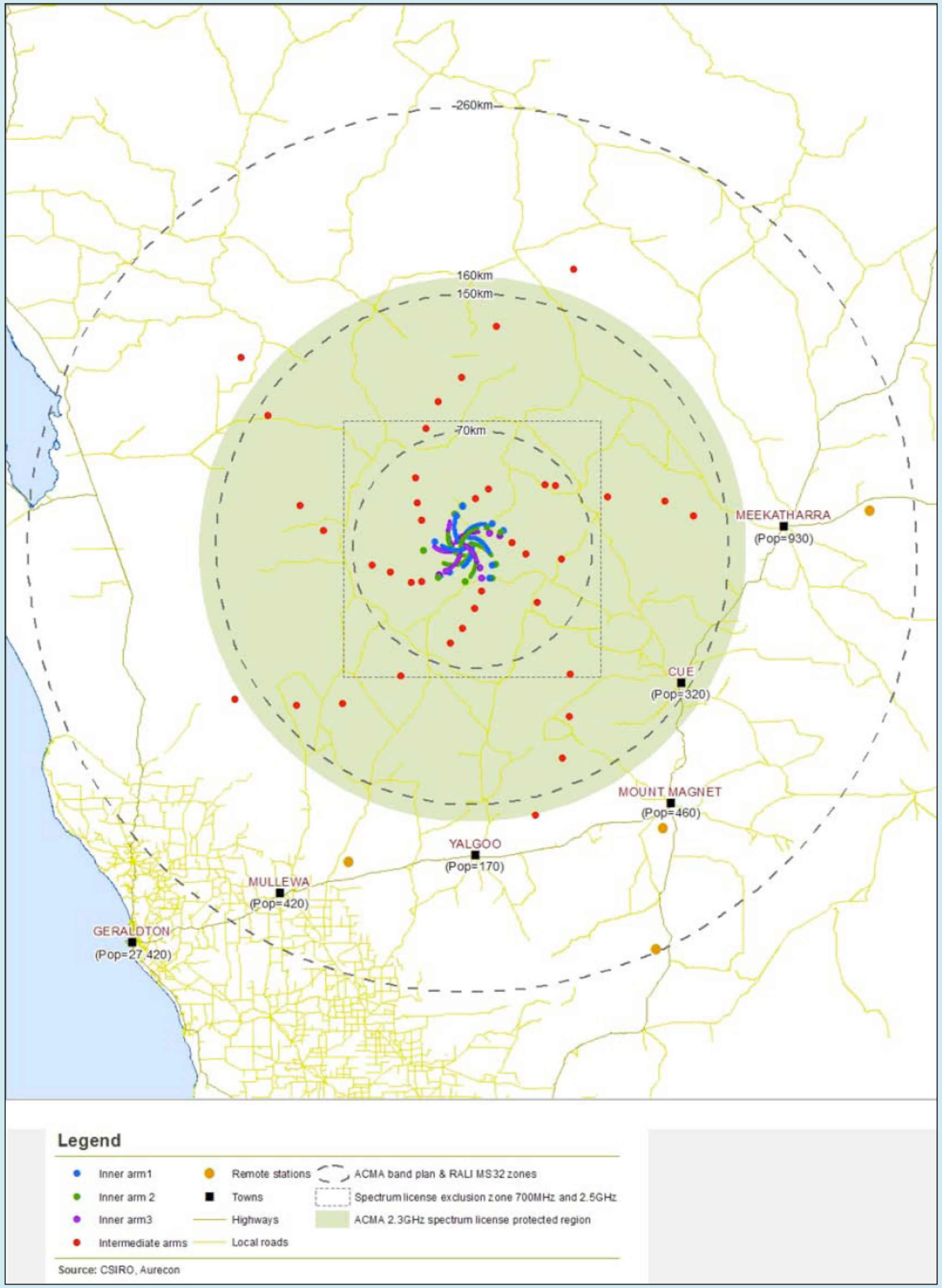
- Remoteness
- Site shielding
- Control of interfering sources
  - Notification, coordination, restriction (of intentional radio devices)
  - Physical site access limitiations
  - Activities near the site (industry, mining, use of electrical appliances, …)
  - Provision of alternative technologies

Radio Quiet Zones
some aspects

Rooted in governmental legislation, defined should be:

- Regulatory authority
- Zones, regions, areas
- Protection, threshold levels in the various zones
- Existing usage/users of the spectrum
- New users, coordination processes
- Procedures in case of conflicts; enforcement
- Exceptions

Australia



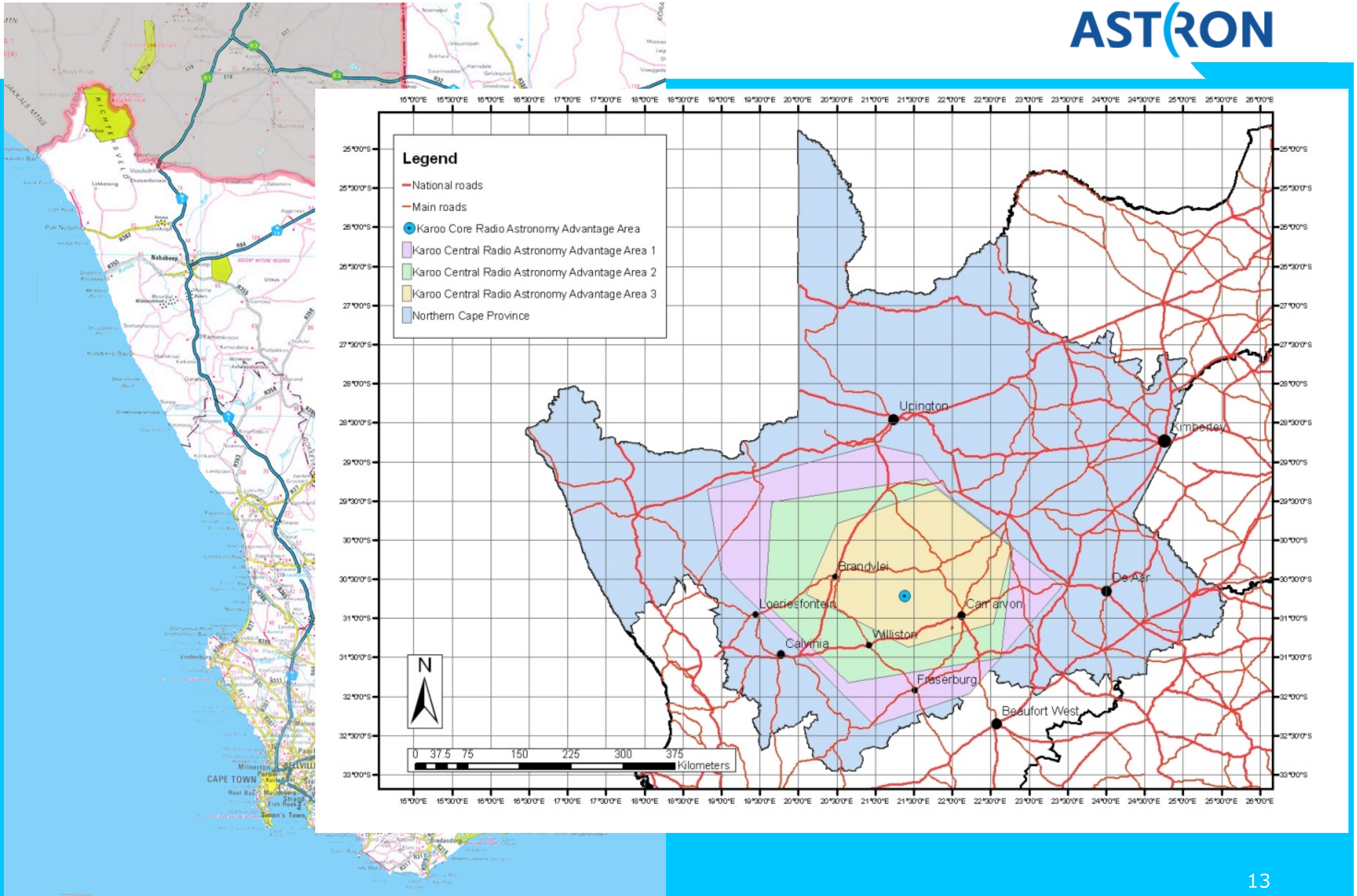
The **Mid West Radio Quiet Zone**, in WA surrounding the **Murchison Radio Observatory** (MRO).

The RQZ of the Mid-West region of WA

Frequency range [MHz]	***Restricted Zone radius [km]***	***Coordination Zone radius [km]***	***Threshold [dBm/Hz]***
70 – 230	150	260	-214
230 – 400	100	180	-222
400 – 520	100	165	-224
520 – 820	100	190	-224
820 – 1,000	100	145	-228
1,000 – 2,300	100	140	-230
2,300 – 6,000	100	120	-232
6,000 – 10,000	100	Not required	-232
10,000 – 25,250	100	Not required	-236

- Restricted – no new apparatus licences (except in extraordinary cases)
- Coordination – if power at the Murchison Radio Observatory (MRO) is above threshold, consultation with CSIRO required

South Africa



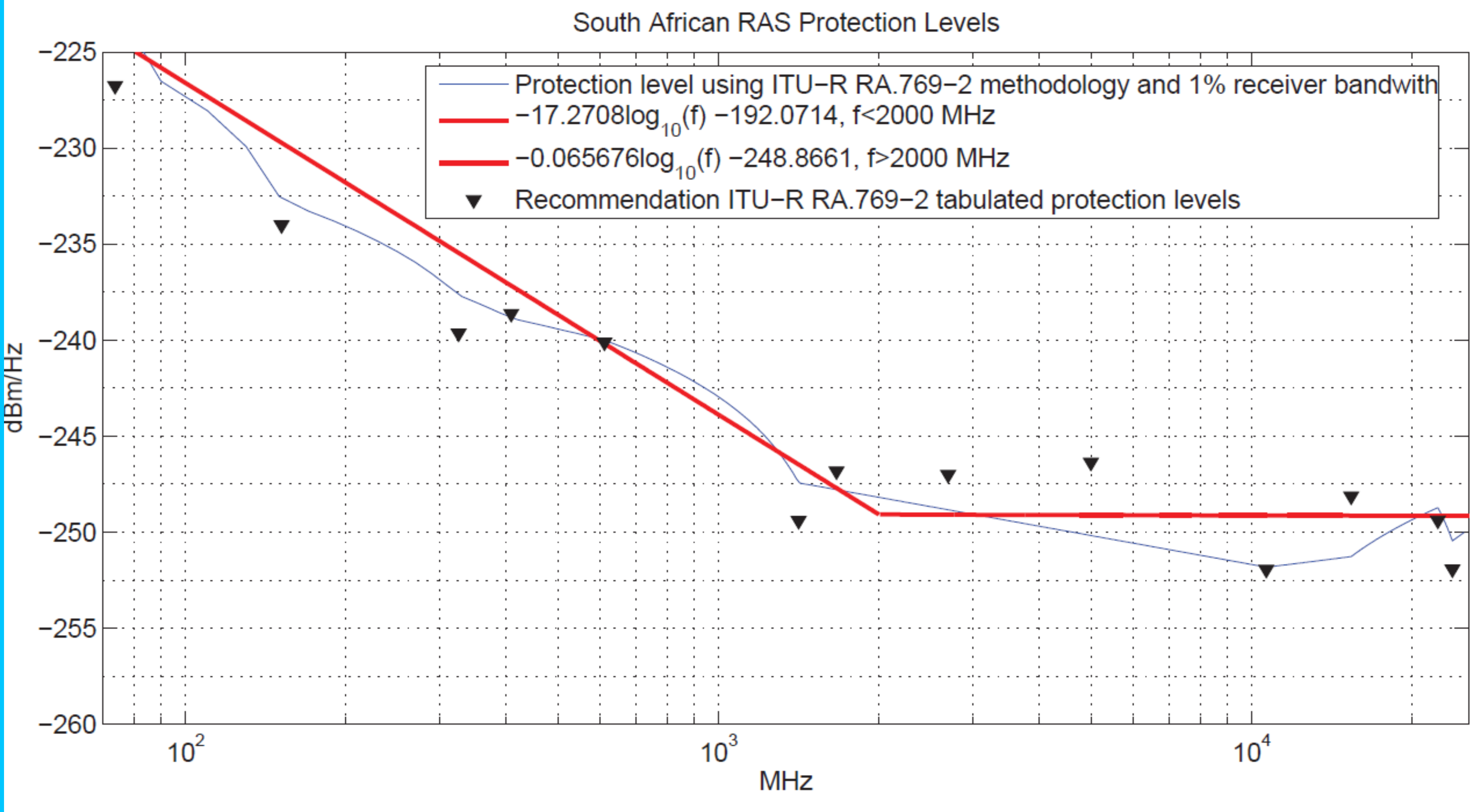
South Africa

The Radio Quiet Protection Legislation in South Africa defines three tiers of protected areas in its Astronomy Geographic Advantage (AGA)Act:

- Core Area – the physical area of the observatory
- Central Areas – surrounding the core area; certain activities and categories of activities prohibited
  - KCAAA1 – 70-2360MHz 123000km^2
  - KCAAA2 – 2360-6000MHz 80000km^2
  - KCAAA3 – 6000-25500MHz 45000km^2
- Coordination Areas – standards are set and activities must comply
  - KCooAAA1 – surrounds KCAAA1 70-1710MHz 373000km^2
  - KCooAAA2 – surrounds KCAAA2 43500km^2

South Africa

These protection levels apply in the Core AAA and in the Central AAA1 at the locations of SKA stations.



Part 3: Self regulation, getting to grips with what will be required…

Inconvenient Truth #1 is that (some) radio observatories have been lax in preventing self-pollution of their radio interference environment.

Inconvenient Truth #2 is that achieving the protection levels for installed equipment at the observatory, as defined in the RQZ legislation, will be extremely difficult and can be costly.

Protecting the Protections
or how do we keep the RQZ quiet

Most, if not all, radio observatories have battled with the problem of self-generated interference.

Ironically, especially those that work in a good **external** interference environment, such as inside some form of protected area.

For the SKA this is

- a **serious risk**,
- and the consequences of it are to be considered **unacceptable.**

The SKA:

- Thousands of dishes
- Hundreds of thousands of aperture array antennas and receivers
- Spread over a very large region, up to a few 1000km
- Built by consortia from all over the world
- With unprecedented sensitivity
- With continuous frequency coverage from 50 MHz to >15 GHz.

Protecting the Protections
or how do we keep the RQZ quiet

For these reasons an SKA RFI/EMI Task Team was formed, with the assignment to produce a reference document:

EMI Protection and Threshold Levels for the SKA

The Task team:

- Axel Jessner (MPIfRA, Germany)
- Richard Lord (SKASA, South Africa)
- Hans van der Marel (ASTRON, The Netherlands)
- Rob Millenaar (SKAO/ASTRON, International, The Netherlands)
- Howard Reader (UStellenbosch, South Africa)
- Franz Schlagenhaufer (ICRAR, Australia)
- Carol Wilson (CSIRO, Australia)

EMI Protection and Threshold Levels for the SKA

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In the document the distinction is made between:

- **Protection Levels**

  The levels of EMI deemed detrimental for SKA observations, and defined at the receiver input.

- **Threshold Levels**

  The levels of EMI that a given device may radiate, such that the level of EMI received at any receiver input does not exceed the Protection Levels.

EMI Protection and Threshold Levels for the SKA

Outline of the document:

1. Introduction
    1. Scope
    2. Nature and Impact of interference on Radio Telescopes
    3. Prevention of self-generated interference
2. Radio Power Threshold Levels
    1. For Radiated Radio Power
    2. For Conducted Radio Power
    3. For Pulsed Emissions
3. Appendix A: Derivation of Levels
4. Appendix B: Dealing with Exceptions
5. Appendix C: Guidelines for good EMI Practice
6. Appendix D: Measurement and Validation

EMI Protection and Threshold Levels for the SKA

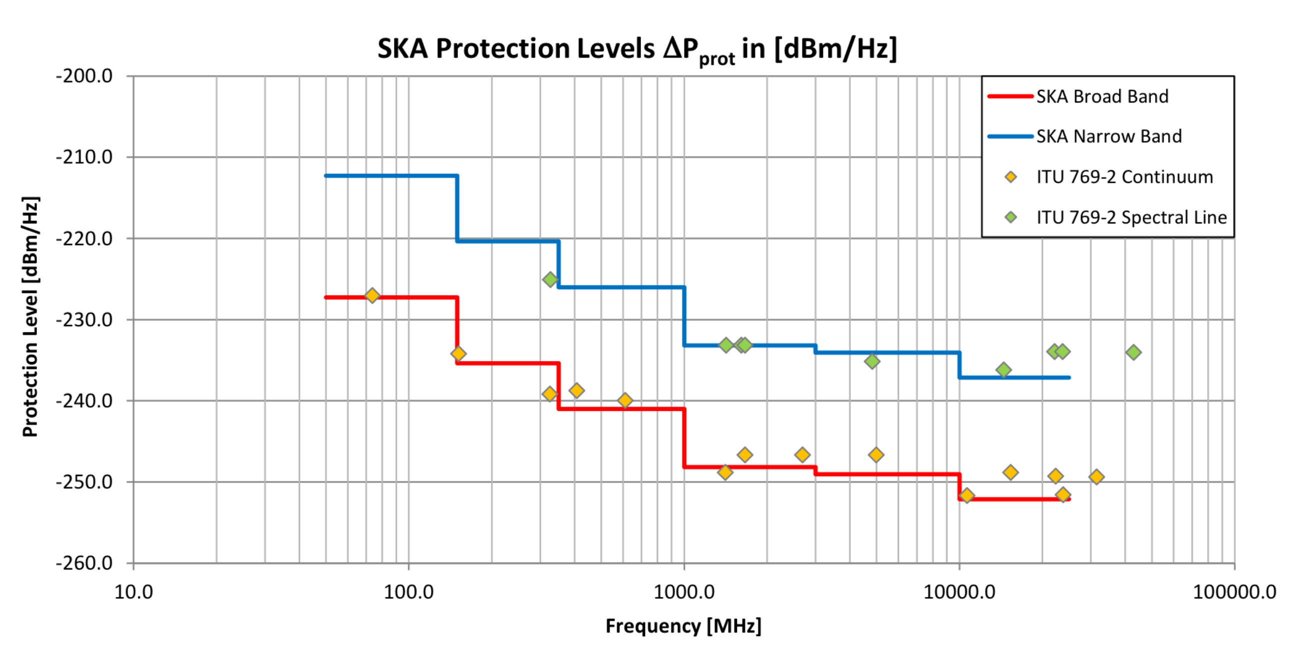
Principles used:

- The two SKA sites shall have the **same** protection levels
- Radiated radio power threshold levels are specified for pre-defined **zones** and **frequency bands**.
- Start from **RA769-2**, using the similar assumptions, interpolate for use across the frequency range of interest.
- Provide levels for **broad** ($\sim f_c.10^{-2}$) and **narrow** band ($\sim f_c.10^{-5}$) cases
- Provide levels for **pulsed** emissions
- **Threshold** levels derive from **Protection** levels via **propagation** losses.

EMI Protection and Threshold Levels for the SKA

SKA Protection Levels

Frequency Band	Centre of Band	System Noise Temperature	Broad Band			Narrow Band		
[MHz]	[MHz]	[K]	ΔP_{prot} [dBm/Hz]	RBW [MHz]	ΔP_H [dBm]	ΔP_{prot} [dBm/Hz]	RBW [kHz]	ΔP_H [dBm]
50 – 150	100	608	-227	1	-167	-212	1	-182
150 – 350	250	163	-235	3	-171	-220	3	-186
350 – 1000	675	81	-241	10	-171	-226	10	-186
1000 – 3000	2000	22	-248	20	-175	-233	20	-190
3000 – 10000	6500	22	-249	30	-174	-234	30	-189
> 10000	18000	28	-252	200	-169	-237	200	-184



SKA Threshold Levels

Propagation loss consists of:

1. Free space loss, using Friis transmission equation
2. Excess loss above free space, due to terrain and atmospheric effects.

ITU Rec. P.1546-5 is used to calculate the total propagation loss.

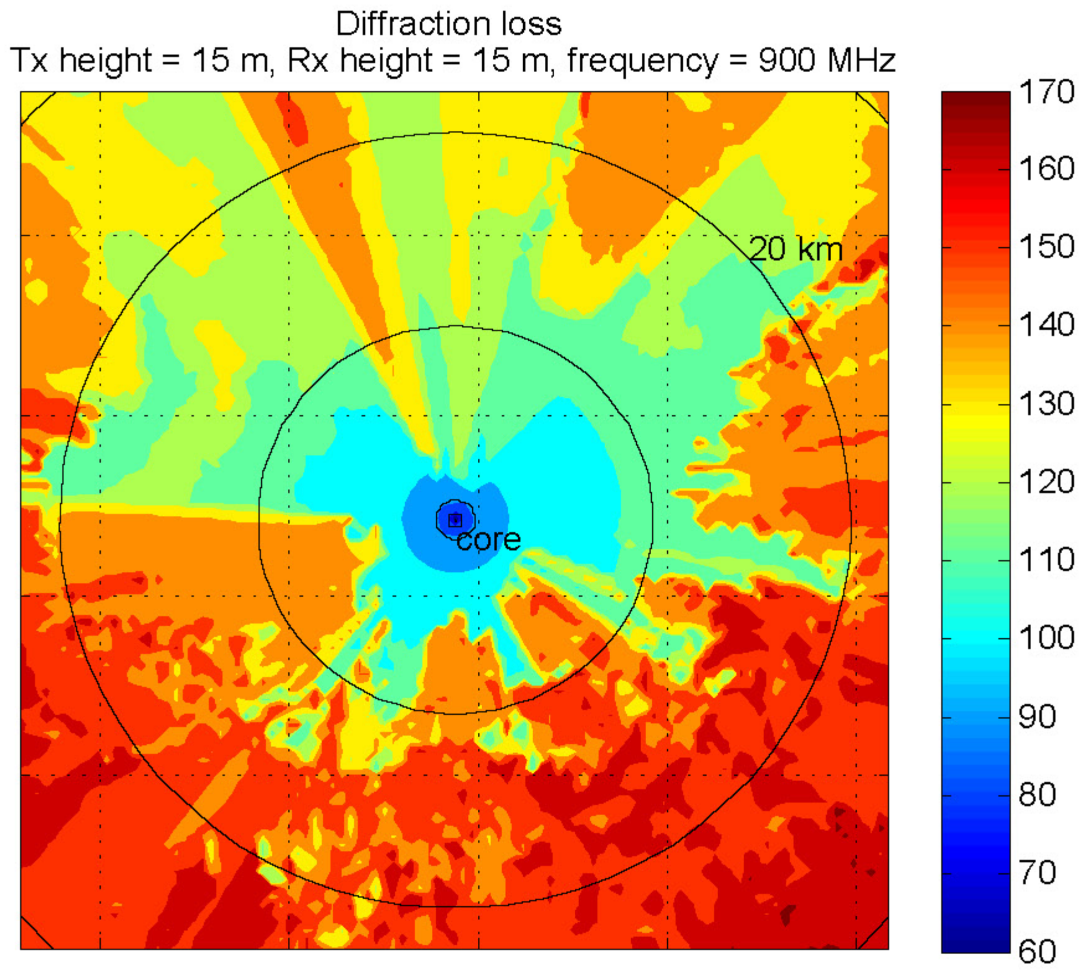
- This recommandation is an empirical model that applies free space loss, the effect of diffraction over the earth (assuming average terrain variation) and atmospheric effects such as troposcatter or ducting, although these are not significant at the distances under consideration.
- Appendix B deals with cases where P.1546 does not represent the actual terrain. Diffraction loss can be calculated using the methodology of Recommendation **ITU-R P.526-13** Section 4.5 [10]. A digital terrain map for the region is required.

(Assumed receiver height at $d<1$km is 2m for $f<350$MHz, 15m for $f>350$MHz. At $d>1$km height is 15m.)

EMI Protection and Threshold Levels for the SKA

SKA Threshold Levels

Appendix B deals with cases where P.1546 does not represent the actual terrain. Diffraction loss can be calculated using the methodology of **Recommendation ITU-R P.526-13** Section 4.5 [10]. A digital terrain map for the region is required.



EMI Protection and Threshold Levels for the SKA: **Threshold level table**

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Zone		Frequency Band	Broad Band		Narrow Band	
#	Definition	[MHz]	RBW [MHz]	Limit [dBm/RBW]	RBW [kHz]	Limit [dBm/RBW]
1	< 10m(*)	50 – 150	1	-161	1	-176
		150 – 350	3	-155	3	-170
		350 – 1000	10	-148	10	-163
		1000 – 3000	20	-143	20	-158
		3000 – 10000	30	-132	30	-147
		> 10000	200	-117	200	-132
2	10m – 100m(*)	50 – 150	1	-141	1	-156
		150 – 350	3	-135	3	-150
		350 – 1000	10	-128	10	-143
		1000 – 3000	20	-123	20	-138
		3000 – 10000	30	-112	30	-127
		> 10000	200	-97	200	-112
3	100m – 1km	50 – 150	1	-117	1	-132
		150 – 350	3	-115	3	-130
		350 – 1000	10	-108	10	-123
		1000 – 3000	20	-103	20	-118
		3000 – 10000	30	-92	30	-107
		> 10000	200	-77	200	-92
4	1km – 10km	50 – 150	1	-74	1	-89
		150 – 350	3	-68	3	-83
		350 – 1000	10	-77	10	-92
		1000 – 3000	20	-74	20	-89
		3000 – 10000	30	-66	30	-81
		> 10000	200	-52	200	-67
5	10km – 50km	50 – 150	1	-41	1	-56
		150 – 350	3	-31	3	-46
		350 – 1000	10	-37	10	-52
		1000 – 3000	20	-31	20	-46
		3000 – 10000	30	-21	30	-36
		> 10000	200	-5	200	-20

EMI Protection and Threshold Levels for the SKA: **Threshold level graphs**

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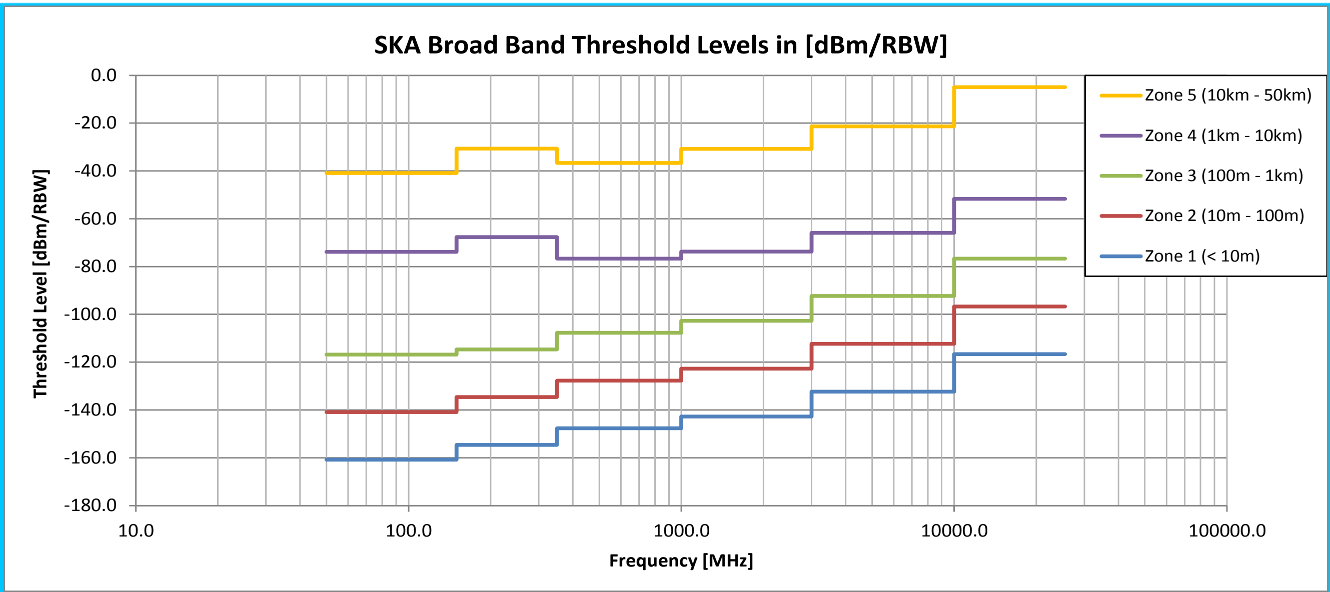

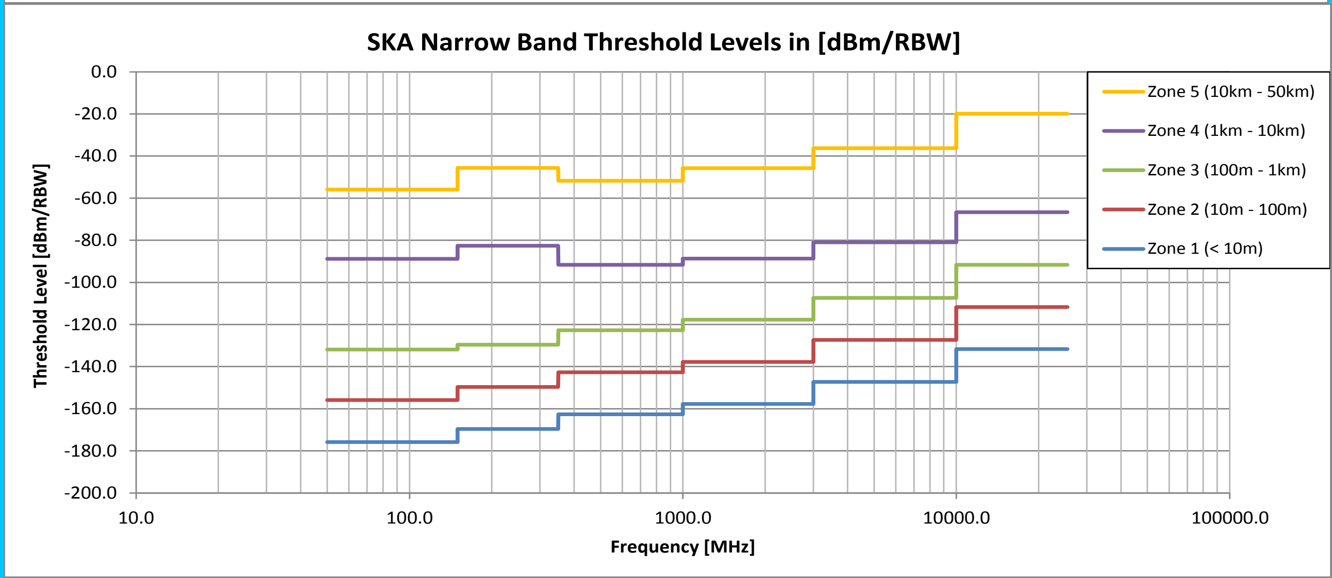

EMI Protection and Threshold Levels for the SKA

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The document deals with:

- Radiated vs. Conducted coupling of interference
- Common mode currents
- Guidelines for good EMC practice (beyond the scope of this presentation)
- Measurement and Verification (beyond the scope of this presentation)

EMC Management Plan

A plan must come into effect in which procedures are defined, and details are given on:

- Ensuring compliance with the EMI Protection and Threshold Levels as given in the document
- Acceptance procedures
- EMI policing of the site
- Required personnel dedicated to RFI/EMI/EMC
- Further describing how to deal with non-compliance
- How to handle non-compliance by other (prior) users of the site
- Executing routine and incidental spectrum monitoring activities
- Maintaining an RFI database
- Building up awareness and responsibility in workers and visitors

Summary

For any radio telescope, but certainly for the next big thing in radio astronomy observatories, the SKA, the establishement of a Radio Quiet Zone must:

- be appropriate in coverage of the 'external' radio hazards
  - Frequency range
  - Extent
  - Protection levels
  - Access, Legislation, Enforcement
- and must go hand in hand with a policy of preventing 'self-pollution'
  - Publish requirements with Protection and Threshold levels
  - Guidelines for best EMC practice
  - Methods for compliance measurement
  - Monitoring activities