SKA SYSTEM EMI/EMC CONTROL PLAN FOR PROCUREMENT AND MANUFACTURING PHASE

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LIST OF ABBREVIATIONS

AA.....Array Assembly
AIV.....Assembly, Integration and Verification
ACMA.....Australian Communications and Media Authority
ARQZWA.....Australian Radio Quiet Zone Western Australia
BW.....Bandwidth
CDR.....Critical Design Review
CM.....Configuration Management
CoC .....Certificate of Conformance
CISPR .....International Special Committee on Radio Interference
COTS .....Commercial Off-the-Shelf
CPF .....Central Processing Facility
CSIRO .....Commonwealth Scientific and Industrial Research Organisation
CWP .....Construction Work Package
ECP .....Engineering Change Proposal
EM .....Electromagnetic
EMC .....Electromagnetic Compatibility
EMCCP .....EMC Control Plan
EMI .....Electromagnetic Interference
FAT.....Factory Acceptance Test
IEC .....International Electrotechnical Committee
ITU.....International Telecommunications Union
KAPB.....Karoo Array Processing Building
KDRA .....KAPB Data Rack Area
LOW .....SKA Low-Frequency Array
LNA .....Low Noise Amplifier
MID.....SKA Mid-Frequency Array
NCR.....Non-Conformance Report
NRB.....NCR Review Board
PM .....Project Manager
PSD .....Power Spectral Density
QA .....Quality Assurance
QTP .....Qualification Test Procedure
RAS .....Radio Astronomy Service
RBW .....Resolution Bandwidth
RFI.....Radio Frequency Interference
RPF .....Remote Processing Facility
RQZ.....Radio Quiet Zone
SARAO.....South African Radio Astronomy Observatory

SAT .....Site Acceptance Test

SE.....System Engineering

SKA .....Square Kilometre Array

SKAO .....SKA Observatory

TRR .....Test Readiness Review

TRB .....Test Review Board

1 Introduction

Radio frequency interference (RFI) presents the single biggest threat to the scientific performance of a radio astronomy facility. RFI is defined in [AD1] as all unwanted, non-astronomical electromagnetic (EM) signals received by the telescope that are sufficiently strong to have the potential of creating false detections of astronomy signals or even influence the telescopes' design.

The mandate of the RFI/EMC Team of the Square Kilometre Array Observatory (SKAO) is to **ensure the EMC compliance** of all the equipment/systems that will operate in the astronomy protected areas as part of the Square Kilometre Array (SKA) Telescopes. This is achieved through a developed electromagnetic compatibility (EMC) compliance workflow explaining the roles and responsibilities of the contractors and SKAO from contract award to commissioning. This document lays out the roadmap for the EMC requirements of systems, sub-systems or components to become compliant to SKAO telescope protection levels defined in [AD1]. It considers EMC pre-compliance testing, as well RFI qualification and site acceptance tests (SAT).

1.1 Purpose of the Document

The purpose of this document is to describe the process by which the SKA Observatory will achieve EMC compliance of both SKA-Low and SKA-Mid through the *Procurement* and *Manufacturing* phases. A top down approach is used starting at the system level control plan, where the integration of all products will create a compliant system, followed by a description of a typical EMC control workflow diagram for a product/system describing different milestones and stakeholders involved in the process. This document also includes a section on EMC requirements, aimed to expand on the application of the SKA EMI/EMC standards and procedures document.

The *EMC Compliance Roadmap* described in this document is based on a typical scenario, and it is possible that the implementation of the workflow, depending on the complexity and context where the equipment will be installed on site, will require tailoring for a particular product/system. The application of this roadmap shall be described in the EMC Control Plan (EMCCP) of each product/system.

The holistic SKAO *EMC Management Plan* [AD3] document structure is shown in **Figure 1**.

1.2 Scope of the Document

The stakeholders identified in the *EMC Compliance Roadmap* are shown in **Figure 2** and consists of a *Contractor* and the *SKA Observatory*. The *Contractor* will appoint an RFI/EMC Specialist as part of the *Contractor Project Team*, while the *SKA Observatory Project Team* will consist of a Project Manager, Supervisor and Compliance Team. The Compliance Team will be made up of the SKAO RFI/EMC Specialist and Quality Assurance Specialist. It is important to note that the Supervisor will not make any direct RFI/EMC decisions, but would always revert to the SKAO RFI/EMC Specialist(s). The various phases of a product or system's life cycle, as depicted in the simplified schematic in **Figure 3**, are considered in the EMC Compliance Roadmap (*note that each stage might not be applicable to all contracts*).

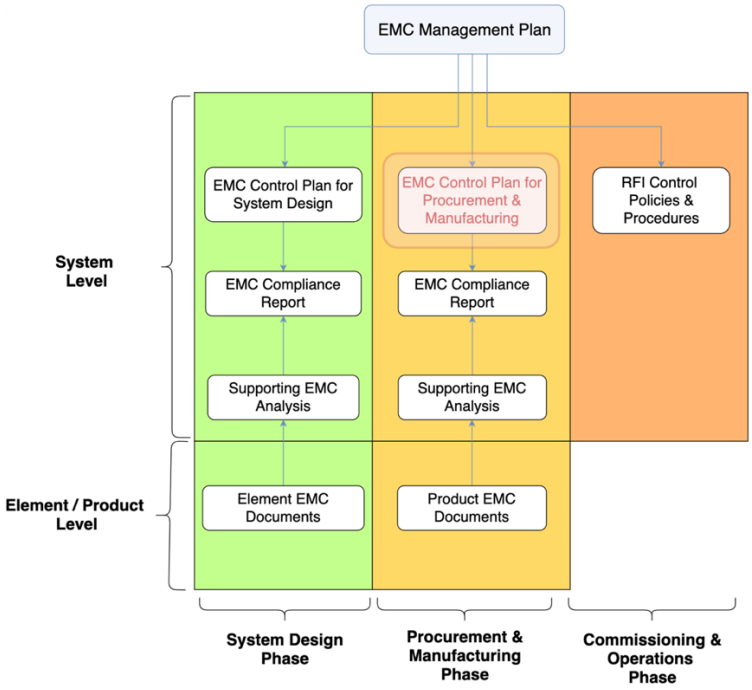

Figure 1 – SKAO EMC Management Plan document structure. The *SKA System EMC Control Plan for Procurement and Manufacturing* (this document) is indicated in red.

The various phases considered during the product or system's life cycle include:

1. Contract Preparation, Tender and Contract Award
2. Contractor's Design Submission Review
3. Prototyping and EMC Pre-Compliance Testing (Contractor In-House Testing)
4. Pre-Production EMC/RFI Qualification (Laboratory Testing)
5. Production (In-House and Laboratory Testing)
6. Installation (Site Acceptance Testing)
7. Maintenance

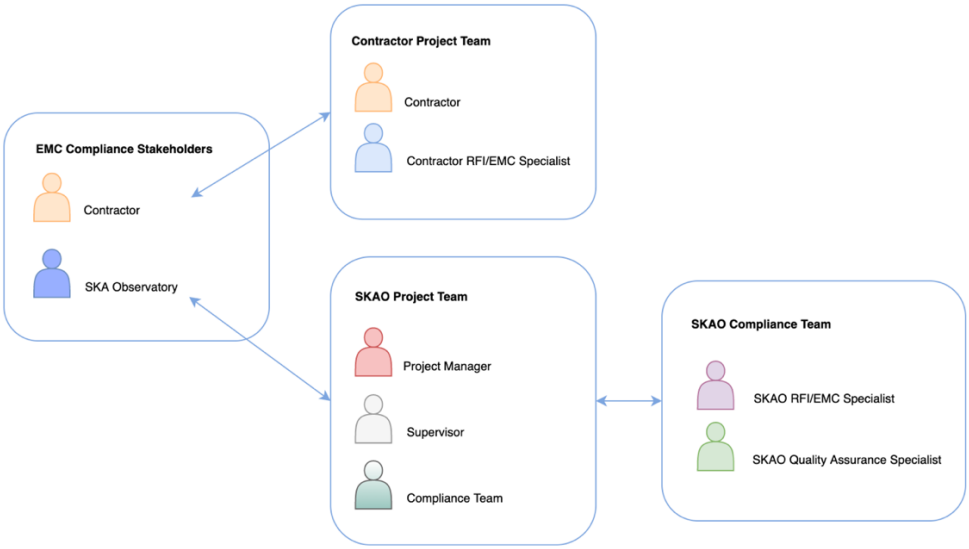

Figure 2 – The EMC compliance stakeholders include (1) *Contractor* (2) the *SKA Observatory*. The Contractor will appoint an RFI/EMC Specialist as part of the Contractor Project Team, while the SKAO Project Team will consist of a Project Manager, Supervisor and Compliance Team (SKAO RFI/EMC Specialist and Quality Assurance Specialist).

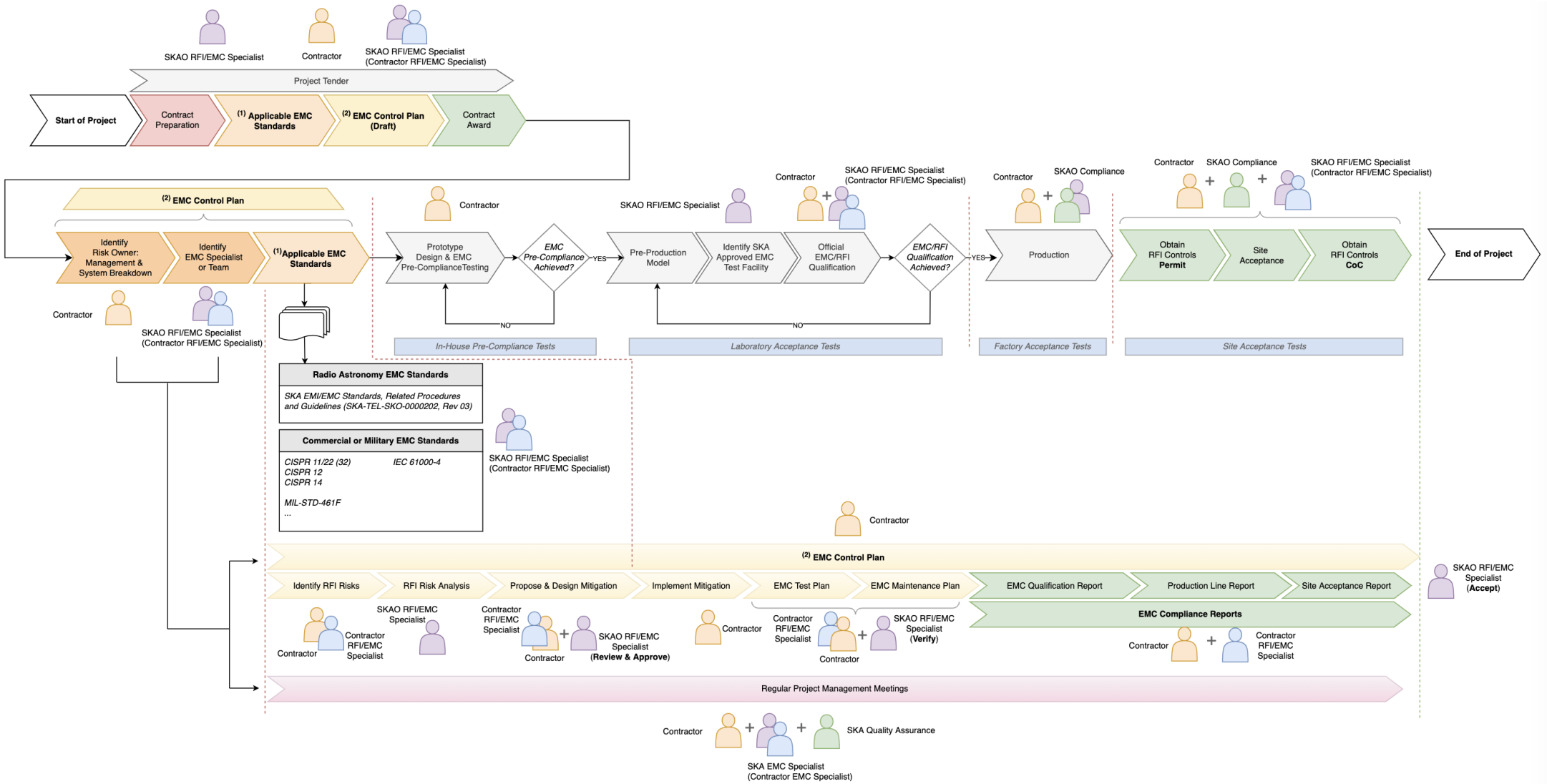

Figure 3 – A simplified schematic of the *EMC Compliance Roadmap*.

2 References

2.1 Applicable Documents

The following documents are applicable to the extent stated herein. In the event of conflict between the contents of the applicable documents and this document, **the applicable documents** shall take precedence.

[AD1] P. Dewdney, G.-H. Tan, H. Smith, T. Tzioumis and J. Jonas, *SKA EMI/EMC Standards, Related Procedures and Guidelines*, Document Number SKA-TEL-SKO-0000202, Rev 03, SKA Organisation, Jodrell Bank Observatory, UK, 2017-03-13.

[AD2] ITU-R RA.769, "*Protection Criteria used for Radio Astronomy Measurements*", International Telecommunications Union, Recommendation (ITU-R), 2003.

[AD3] F. Di Vruno, "SKA Phase 1 EMI/EMC Management Plan", Document Number SKA-TEL-SKA-1031, Rev 01, SKA Organisation, Jodrell Bank Observatory, UK, 2019-09-03.

[AD4] M. Austin, "*SKA Statement of Work Part 1 General*", Document Number SKA-TEL-SKO-0001027, Rev 01, SKA Organisation, Jodrell Bank Observatory, UK, 2020-04-14.

[AD5] A. MacLeod, "*Roll-out Plan for SKA1_LOW*", Document Number SKA-TEL-AIV-4410001, Rev 09, SKA Organisation, Jodrell Bank Observatory, UK, 2020-06-23.

[AD6] R. T. Lord, D. Gammon and M. Lilley, "*Roll-out Plan for SKA1_MID*", Document Number SKA-TEL-AIV-2410001, Rev 09, SKA Organisation, Jodrell Bank Observatory, UK, 2020-06-09.

[AD7] J. Obiebi, "*SKA Product Quality Assurance Plan*", Document Number SKA-TEL-SKO-0000739, Rev 02, SKA Organisation, Jodrell Bank Observatory, UK, 12 February 2019.

[AD8] T. Cheetham, "*South African Site Information & Instructions: SKA1_MID: Site Information*", Document Number SKA-TEL-SKO-0001040, Rev 01, SKA Organisation, Jodrell Bank Observatory, UK, 2020-10-08.

[AD9] K. Adern and A. Schinckel, "*Australian Site Information: SKA1_LOW*", Document Number SKA-TEL-SKO-0001650, Rev 01, SKA Organisation, Jodrell Bank Observatory, UK, 2020-10-24.

2.2 Reference Documents

The following documents are referenced in this document. In the event of conflict between the contents of the referenced documents and this document, **this document** shall take precedence.

[RD1] J. Jonas and A. J. Otto, "*Applying Telescope Protection Levels to Measurement Data*", Document Number SSA-0008A-038, Rev 01, South African Radio Astronomy Observatory (SARAO), Observatory, Cape Town, South Africa, 19 December 2019.

[RD2] A. J. Otto and C. van der Merwe, "*RFI Zone Definitions for MeerKAT and SKA1*", Document Number SSA-0008N-01A-001, Rev 01, South African Radio Astronomy Observatory (SARAO), Observatory, Cape Town, South Africa, 22 April 2020.

[RD3] Government Gazette, No. 41321, *Regulations on the Protection of the Karoo Central Astronomy Advantage Areas in terms of the Astronomy Geographic Advantage Act, 2007*, No. 1411, p.171, 15 December 2017.

[RD4] Australian Communications and Media Authority (ACMA), "*Radiocommunications (Mid-West Radio Quiet Zone) Frequency Band Plan 2011*", Federal Register of Legislative Instruments F2011L01520, 11 July 2011.

[RD5] Australian Communications and Media Authority (ACMA), RALI MS 32, "*Coordination of Apparatus Licensed Services within the ARQZWA*", Canberra, December 2014.

[RD6] C. Wilson, "*RFI Standards for Equipment to be Deployed on the MRO*", Document Number ASKAP-MRO-001, Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2010-10-15.

[RD7] A. J. Otto, "*Karoo Array Processing Building and Site Attenuation (Summary)*", Document Number M2901-0000-075, Rev 01, Square Kilometre Array (SKA) South Africa, Pinelands, Cape Town, South Africa, 27 July 2017.

[RD8] H. Smith, "*Approved national & international standards for referencing in SKA project EMC documentation*", Document Number SKA-TEL-SKO-0000691, Rev 01, SKA Organisation, Jodrell Bank Observatory, UK, 2017-03-13.

[RD9] A. Tiplady, "*SARAO Radio Frequency Interference Policy*", Document Number SSA-0008A-004, Rev 02, South African Radio Astronomy Observatory (SARAO), Observatory, Cape Town, South Africa, 10 July 2020.

[RD10] C. van der Merwe and A. Tiplady, "*Policy for the Control of RFI on the Karoo Site*", Document Number M2900-0000-019, Rev 01, South African Radio Astronomy Observatory (SARAO), Observatory, Cape Town, South Africa, 14 October 2016.

3 Definitions

The following definitions are applicable to this document:

"RFI"	radio frequency interference, including electromagnetic interference (EMI), that poses a detrimental risk of interference to SKA facilities;
"external RFI"	RFI that is generated by assets or infrastructure not defined as SKA facilities, either as a primary or intentional transmission for the purposes of providing telecommunication services, or as a secondary or unintentional transmission as the result of activities or use of the assets or infrastructure;
"internal RFI"	RFI that is generated by SKA facilities, either as a primary or intentional transmission for the purposes of providing telecommunication services, or as a secondary or unintentional transmission as a result of activities or use of the SKA facilities;
"self-generated RFI"	RFI that is generated by the same equipment that is being affected;
"SKA facilities"	meaning all radio astronomy facilities and associated infrastructure established on land under direct management and control of SKAO (South Africa) or CSIRO (Australia), either through rights of ownership, lease agreements or servitude;
"*RFI/EMC Standard*"	refers to the telescope protection levels as defined in the *SKA EMI/EMC Standards, Related Procedures and Guidelines* [AD1];
"*EMC*"	electromagnetic compatibility considers the electrical relationship between different systems or sub-systems, and ensures reliability and safe operation of equipment when exposed to electromagnetic environments;
"*EMI*"	electromagnetic interference refers to unintended radiated or conducted emissions from equipment;
"*Time Occupancy*"	how often an RFI culprit is used, resulting in a percentage of time that an interference signal is present during an observation;
"*Spectrum Occupancy*"	the percentage bandwidth occupied by an interference signal during an observation;
"*Radio Quiet Zone*"	a geographic area within which radio frequency signal levels from radiotelecommunications transmitters are controlled to minimise the strength of the electromagnetic energy within the area;
"*Duty Cycle*"	same as "Time Occupancy";

"*RFI Controls*"	policies and procedures that defines tools to manage the RFI on site, including verification, analysis, record keeping and initiate corrective action (if required);

4 System Level EMC Control Plan

In a complex system such as the SKA telescopes, system level EMC compliance will be achieved through the implementation of rigorous sub-system EMC control plans that will prove compliance of every electrical part of the system. The integration of these sub-systems, however, can sometimes be the source of non-compliances at system level. To verify that the integration of the system remains compliant to the SKA EMI/EMC requirements, reduced system level tests will be included in the commissioning phase of each one of the Array Assembly (AA) stages. This incremental approach will reduce the overall RFI/EMC risk and will allow for feedback to the manufacturing process for necessary corrective actions.

As described in the Assembly, Integration and Verification (AIV) Rollout plans [AD5] and [AD6], the construction of the telescopes following the integration test facility will be divided into 5 stages, called Array Assemblies (AA), starting with AA0.5 and proceeding to AA1 to AA4. Each AA will increase the capabilities of the telescopes by integrating more equipment and functionalities. These AAs will be used as checkpoints to verify EMC compliance of the system, as integrated up to that point. The collection of sub-systems certificates of compliance will be complemented with a reduced EMC system level test during commissioning of each AA. This will specifically address the EMI/EMC compliance of the system and the results of these tests will be included in the system level EMC compliance report to be prepared as a deliverable with the completion of each AA.

The basic flow for System level EMC control considering AA0.5 as the first checkpoint is shown in **Figure 4**. The box in yellow is the *Tender Phase*, where the EMC control plans for each construction work package (CWP) are defined and implemented throughout the different AAs. The EMC compliance report for each CWP is submitted to the SKAO as a deliverable to accept the sub-system. During each AAx the Engineering and Science commissioning teams will perform tests to verify the level 1 (L1) and level 0 (L0) requirements (depending on the number of AA, more complex tests are foreseen according to the capabilities of the AA). The L1 EMI/EMC requirements at system level will be gradually verified by these tests achieving the complete verification after AA4.

Non-Conformances Reports (NCR) are a major pillar of the Quality Assurance (QA) plan [AD7] and considered of major importance for EMC management. The NCRs process allows for early detection of issues and the appropriate corrective action. NCRs will be assessed for criticality (minor/major) and the major NCRs will be analysed by an NRB (NCR review board) where SKAO and the *Contractor* will participate. In an NRB, SKAO will have the final decision on the disposition of the NCR. The resolution of NCRs will feed information for necessary modifications to the production process (to amend the current AA and for the production for next AAs). Each *Contractor* will maintain an NCR logbook with all the minor/major NCRs that will be included in the documentation of each agreed milestone.

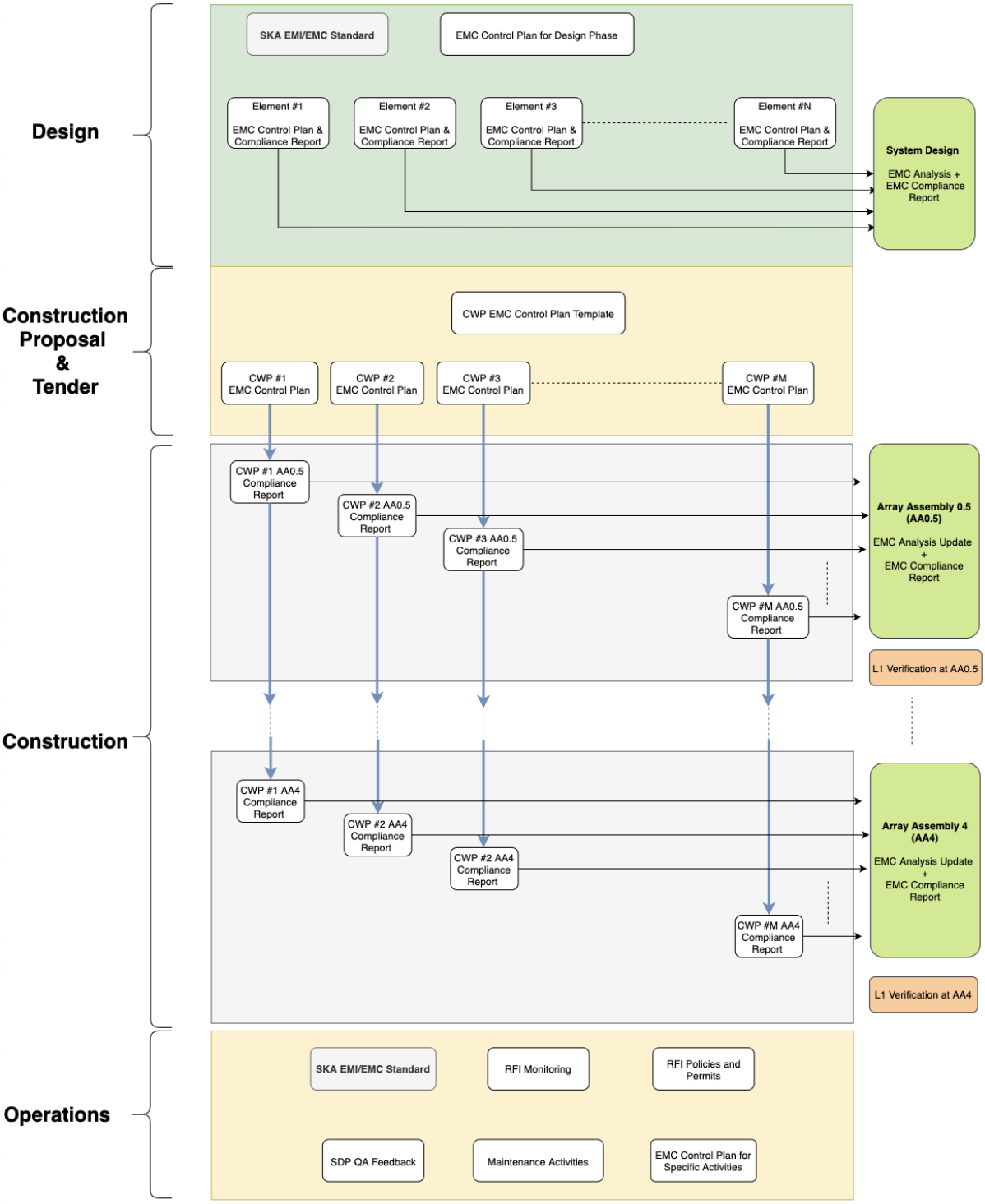

Figure 4 – Proposed EMC control for various phases through AA0.5 to AA4 and operations [AD3].

5 Sub-System and Component Level EMC Control Plan

5.1 Contract Preparation, Tender and Award

An important step in initiating the EMC compliance processes during the Contract Preparation, Tender and Contract Award phases of the project is the identification of *applicable EMC standards*. The intended *location* of the product/system, as well as its *level of emissions* and *time occupancy* of possible interference to the telescope receivers will dictate which EMC standards it should comply to. For example, a device that will be located in an EMC shielded enclosure sufficiently far away from a telescope receiver, might only have to comply to commercial or military EMC standards, while a device located on the telescope itself will have to comply directly to the radio astronomy protection levels defined in [AD1].

5.1.1 Applicable EMC Standards

5.1.1.1 Commercial Standards

Various commercial and military EMC standards exists to ensure that electrical and electronic equipment operate safely and reliably in any electromagnetic (EM) environment, without introducing intolerable EM disturbances to other equipment in that environment. These standards typically apply to commercial off-the-shelf (COTS) products. The International Electrotechnical Commission (IEC) defines the following types of EMC standards and publications:

1. Basic EMC Publications
   Publications that specify general conditions or rules necessary to achieve EMC. These include the *IEC 61000* and *CISPR 16* series publications.

2. Generic EMC Standards
   Generic standards often form building blocks for the development of product standards. These provide a limited number of essential emissions and immunity tests, as well as minimum test levels.

3. Product Specific EMC standards
   These include stand-alone EMC publications that are appropriate for complex systems or those that operate in a special environment, as well as general product standards that incorporates certain EMC clauses. The latter are typically products of a simpler nature and forms part of an amendment to an existing standard.

Examples of typical commercial and military standards of interest to SKAO RFI Risk Analyses include:

- CISPR 11: "*Industrial, Scientific and Medical (ISM) Equipment*"
- CISPR 12: "*Vehicles, boats and internal combustion engines*"
- CISPR 14: "*Household appliances, electrical tools and similar apparatus*"
  CISPR 14-1: Emissions and CISPR: 14-2 Immunity
- CISPR 32: "*Electromagnetic Compatibility of Multimedia Equipment: Emissions Requirements*"
- MIL-STD-461G: "*Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*"

See [RD8] for a complete list of standards.

5.1.1.2 Radio Astronomy Standards

The radio astronomy telescope protection levels defined in [AD1] were derived from the International Telecommunication Union (ITU) Recommendation ITU-R RA.769-2 [AD2] (hereafter referred to as 'RA.769'). RA.769 determines the level of RFI considered detrimental to radio astronomy observatories in the frequency bands allocated by the ITU for radio astronomy service (RAS). It is shown in [AD1] that RA.769 derives thresholds for harmful interference, expressed in Power Spectral Density (PSD), by considering continuum and spectral line observations separately. A threshold is defined as the interference power within a chosen bandwidth (BW) that would produce an error of 10 % in the smallest power that can be detected by the receiver (based on the radiometer equation). An integration time of 2000 s is used with appropriate antenna and receiver noise temperatures at frequencies under consideration.

Threshold levels of interference harmful to radio astronomy observations are highly dependent on the specific nature of the observational parameters employed, such as: *frequency*, *observing bandwidth*, *integration time*, *system temperature*, etc. These set the sensitivity of the telescope under those specific conditions. For that particular sensitivity, the threshold of harmful interference can then be determined by considering the potential error induced by an interfering signal power that cannot be tolerated for that observation [AD1].

For *Continuum* observations a bandwidth ratio of 1% of the observing frequency is adopted and verification is carried out against the power threshold at the antenna guided wave input applied to the following equation where *f* is frequency in MHz:

$$\mathrm{PSD}\left[\frac{\mathrm{dBm}}{\mathrm{Hz}}\right] = -17.2708\log_{10}(f) - 192.0714 \quad \text{for f} < 2\ \mathrm{GHz}$$
$$\mathrm{PSD}\left[\frac{\mathrm{dBm}}{\mathrm{Hz}}\right] = -0.065676\log_{10}(f) - 248.8661 \quad \text{for f} \geq 2\ \mathrm{GHz}$$

Spectral Line observations uses a bandwidth of 0.001% of the observing frequency (equivalent to the 3 km/s Doppler resolution). [RD1] provides a standard way of applying radio telescope protection levels to measurement data and emphasises the importance of bandwidth compensation when considering interference signal (Δf_{sig}), measurement receiver (Δf_{meas}) and radio astronomy protection bandwidths (Δf_{thresh}). The measured PSD_m should be compared to two threshold levels: the original continuum threshold levels (after summing adjacent power contributions to obtain an equivalent continuum bandwidth), and the bandwidth compensated spectral line threshold, i.e.

$$\mathrm{PSD_{comp}} = \mathrm{PSD_{thresh}} \times \left(\frac{\Delta f_{\mathrm{thresh}}}{\Delta f_{\mathrm{meas}}}\right)$$

5.1.2 Radio Quiet Zones, RFI Zones and Equipment Classification

The SKA sites were selected to be as free as possible of external terrestrial RFI over significant bandwidths (BW) and will be maintained as such through the establishment of radio quiet zones (RQZs). RQZ legislation for both sites provide legal requirements for limitation of levels of RFI from any source on the sites between 70 MHz and 25.25 GHz (Australia) and 100 MHz to 25.5 GHz (South Africa).

Local RFI Zones at each of the sites are furthermore defined to control possible internal RFI in close vicinity of the telescope receivers. These RFI Zones are typically used when issuing *RFI Controls* [RD10], such as an RFI Permit or RFI Certificate of Conformance (CoC), which will restrict the use of equipment to certain zones and certain times of day.

5.1.3 Draft EMC Control Plan

A tenderer is expected to present a *Draft EMC Control Plan* (EMCCP) along with the documentation pack for tender. The EMC Control Plans that formed part of the Critical Design Review (CDR), as well as the EMCCP template in [AD1], can be used as a starting point for the development of the procurement and manufacturing phase EMCCP.

The *Draft EMCCP* will include as a minimum:

1. High level description of the product/system;
2. Stakeholders, Roles and Responsibilities associated with the EMC compliance of the product;
3. Preliminary assessment of the high-risk items.

5.2 EMC Control Plan

Once a contract has been awarded, the *Contractor* will be required to further develop the EMC Control Plan (EMCCP) of the product/system they will be providing. It is strongly recommended that an *external EMC specialist* be appointed by the *Contractor* to take this activity forward with the collaboration from the SKAO EMC/RFI Specialist(s), forming an EMC Specialist Team. The *Contractor*, together with the EMC Specialist Team, will be responsible to produce an EMC Control Plan (EMCCP) as per the processes presented in [AD1]. The EMCCP will be a living document for the duration of the project and can contain an EMC Test Plan and EMC Maintenance plan if required. The EMCCP that formed part of the CDR, as well as the sample EMCCP template in [AD1], can be used as a starting point for the further development of the procurement and manufacturing phase EMCCP.

In addition to the sample EMCCP in [AD1] the document will consist of:

1. **System / Product Breakdown**
   A description of the system / equipment that is to be deployed to site, including the planned location of use as per the RFI Zones. The description shall give an overview of the timescales for the system deployment.

2. **Risk Identification and Risk Analysis / Qualification**
   Identify the RFI risks from all electronic and electrical culprit equipment.
   - *This shall include a desktop propagation study of the expected frequencies and power levels to telescope receivers in the Core and in the Spiral Arm locations.*

   Risk shall be classified as to:
   - *Low Noise Amplifier (LNA) damage,*
   - *Exceeding Saturation Levels and*
   - *Exceeding the Telescope Protection Threshold Levels (for spectral line and continuum).*

   The risk quantification shall indicate what items are permanent and what are temporary.
   Risks shall be classified in terms of criticality including severity and probability.

3. **RFI Risk Mitigation Measures**
   Planned RFI mitigation measures during the various phases such as:
   - *Design / Development Phase*
   - *Tender Phase*
   - *Commissioning Phase*
   - *Operations and Maintenance Phases*

4. **RFI Controls Required**
   Identify the RFI Controls (RFI Permits, CoCs) that will be required for the system, including any proposed restrictions on the permits such as limitations on location (RFI Zones) and time of use.

5. **RFI Maintenance Plan**
   Identify the RFI Maintenance Plan that will be required to ensure EMC compliance for the duration of the system / product's life cycle.

6. **Roles and Responsibilities**
   Define the roles and responsibilities to implement the EMC Control Plan for this system/product.

5.3 Contractor's Design Submission Review

A design submission will be received by the PM or Supervisor. Through these channels the SKAO RFI/EMC Specialist will review the design submission. During this process the RFI/EMC aspects of the detail design will be analysed, and mitigation measures will be proposed. The RFI/EMC aspects of the detail design will be *accepted by the SKA RFI/EMC Specialist(s)* and implemented by the *Contractor*. It is important to note that the SKA RFI Specialist is not the design engineer responsible to achieve compliance of the product / system but will rather verify compliance to the SKA EMC Standards.

5.4 Prototyping and Pre-Compliance EMC/RFI Testing

The *Contractor* will implement the RFI mitigation design and the prototyping design. EMC pre-compliance testing on the prototype is recommended to increase design confidence. After successful pre-compliance testing, depending on the complexity of the product and the applicable EMC requirements, reduced qualification testing can be conducted (in one of the EMC testing facilities approved by SKAO) on the prototype to identify design issues. The deliverable will be a pre-production model that can be sent for official RFI Qualification testing with increased confidence that it will comply to the requirements. The results of prototyping pre-compliance and reduced qualification shall be submitted SKAO through the PM or Supervisor to provide feedback and follow the process.

5.5 Pre-Production EMC/RFI Qualification

Once the prototype has been subjected to reduced qualification tests, the pre-production model is ready to start the RFI qualification testing in an SKAO approved EMC facility (as identified during Contract Preparation, Tender and Award phases). The *Contractor* will produce an EMC Test Plan, while together with the *RFI/EMC Specialist Team*, they will produce a *Qualification Test Procedure* (QTP) that will be accepted by the *SKA RFI/EMC Specialist*. The EMC test plan and the QTP will be reviewed and accepted during the Test Readiness Review (TRR) milestone.

The EMC/RFI Qualification will consist of laboratory tests to the required sensitivity identified in the applicable EMC Standards. In the event of a non-compliance, the formal process described in the *Quality Assurance Plan* [AD7] shall be followed to resolve it. The deliverable after the EMC/RFI Qualification will be an *EMC Compliance Report*. Formal acceptance of the qualification test results is reviewed by the Test Review Board (TRB). Once qualification is achieved, the production stage can proceed.

5.5.1 Configuration Management

Following the configuration management processes in [AD4], any Engineering Change Proposal (ECP) that might impact RFI/EMC compliance will have to be analysed and assessed. This will be important to ensure continuity between the configuration qualified during the Pre-Production EMC/RFI Qualification campaign and the design going into Production. There is a high probability that a major change with impact to the RFI/EMC compliance will result in a re-qualification process.

5.6 Production

During the production phase the Supervisor can be accompanied by the SKA Quality Assurance Specialist to inspect the production line items at various intervals. EMC testing to ensure workmanship during the production line will also be required at various checkpoints, as defined in the EMC Test Plan of the product, to ensure the same compliance as achieved during the pre-production EMC/RFI Qualification. These tests will form part of the Factory Acceptance Test (FAT) and the results will be recorded as part of the QA register for each serial numbered item that will be going to site.

5.6.1 Configuration Management

Following the configuration management processes in [AD4], any Engineering Change Proposal (ECP) that might impact RFI/EMC compliance will have to be analysed and assessed. This will be important to ensure continuity between the configuration qualified during the Pre-Production EMC/RFI Qualification campaign and the design going into Production. There is a high probability that a major change with impact to the RFI/EMC compliance will result in a re-qualification process.

5.7 Installation and Site Acceptance

Detailed description of site acceptance processes are given in [AD8] and [AD9]. With the appropriate checks in the QA register, a product will be issued an RFI permit or an RFI CoC depending on the nature of the product and the final installation/usage RFI zone. For products to be installed in high risk RFI zones, a post-installation test will be conducted by SKAO to verify that the installation has not affected the EMC compliance of the product. This will be a site acceptance test (SAT) that will form part of the EMC Test Plan document. No equipment shall be installed on site prior to obtaining the necessary RFI Controls. Typical RFI Controls include:

1. **RFI Permit**
   An RFI Permit will be issued by the SKAO RFI/EMC Team, as well as host country Site Manager, that will allow equipment to be used on a temporary basis. The permit will have an expiry date and will typically restrict the equipment's use to a specific location or RFI Zone, as well as limited times during the day when it can be operated.

2. **RFI CoC**
   A Certificate of Conformance (CoC) will be issued to equipment that will be installed permanently on site. This can only be obtained if the EMC/RFI Qualification was achieved and the necessary EMC Compliance Report and EMC Production Line Compliance Report(s) were reviewed and accepted. The CoC can also restrict the location of installation to a specific RFI Zone.

3. **RFI NCR or Notice**
   If during the usage of the product/system, or during the post-installation tests the requirements for a permit or CoC were not met, a Non-Conformance Notice will be issued, and corrective actions will have to be conducted to obtain a Permit/CoC.

Once the applicable RFI Controls were obtained, the equipment can be installed on site. There may be EMC tests scheduled at various intervals or checkpoints as defined in the EMC Test Plan document to ensure workmanship and EMC compliance. At the end of the installation a Site Acceptance Test (SAT) will be performed to ensure EMC compliance.

5.8 EMC/RFI Maintenance

The *Contractor* must provide a detailed plan on how the EMC Compliance of the equipment will be ensured through regular inspection and maintenance. This will be required from the *Contractor* as part of *the EMC Control Plan*.