



Finanziato  
dall'Unione europea  
NextGenerationEU



Ministero  
dell'Università  
e della Ricerca



Italiadomani  
PIANO NAZIONALE  
DI RIPRESA E RESILIENZA



INAF  
ISTITUTO NAZIONALE  
DI ASTRONOMIA

# MeerKAT Band 5b Receivers

## Technical Specifications

**Document Number:** E-MKT-5BR-INA-SPE-001

**Document Version:** 01

**Document Type:** Specification (SPE)

**Released On:** 2024-02-29

<b>Owner :</b> Pietro Bolli		2024-02-29
<b>Approved by:</b>		2024-02-29
<b>Released by:</b>		2024-02-29
Name	Signature	Date

PNRR  
Missione 4 • Componente 2  
Investimento 3.1

STILES – IR000034  
CUP C33C22000640006

## Authors

Name	Affiliation
Pietro Bolli	INAF-OAA
Francesco Schillirò	INAF-OACt
Enrico Giro	INAF-OAP
Ugo Di Giammatteo	INAF-OAR

## Change Record from previous version

Date	Affected Section(s)	Changes / Reason / Remarks
2024/02/29	All	First issue

# Contents

<b>1. Introduction</b>	<b>4</b>
1.1 Purpose	4
1.2 Context and system coverage	4
1.3 Conventions, Definitions, Abbreviations and Acronyms	5
1.4. References	7
1.4.1 Applicable Documents	7
1.4.2 Reference Documents	8
<b>2. General Overview</b>	<b>9</b>
2.1. System Environment and Boundaries	9
2.2. Architecture Description	9
2.3. Interfaces Description	12
2.4. System Functionality	16
2.5. Assumptions	16
<b>3. Environmental Conditions</b>	<b>17</b>
<b>4. System Requirements</b>	<b>21</b>
4.1. Functional Requirements	21
4.2. Operational Requirements	29
4.3. External Interface Requirements	32
4.4. Quality Requirements	32
<b>5. Recommendations</b>	<b>37</b>

# 1. Introduction

## 1.1 Purpose

This document contains the requirement specifications for the supply of cryogenics, dual-polarisation, single-pixel radio astronomical front-ends operating in the frequency band 8.3 – 15.4 GHz (also called band 5b), to be installed in the 13.5-m MeerKAT radio telescopes located in South Africa, precursor to the SKA telescope.

MeerKAT is not planned, due to funding constraints, to be equipped with receivers operating in band 5b. Furthermore, the SKAO has no plans to retrofit these receivers onto the 64 MeerKAT dishes, when incorporated in the SKA array.

The MeerKAT band 5b receivers (also indicated as “the receivers” in the following) will thus allow high impact science with MeerKAT in the run up to SKA and providing benefits also to the SKA, with a significant increase of sensitivity and substantial enhancement of image fidelity for extended emission.

This document is targeted to the Economic Operators that intend to submit an offer for the design and development of the receivers.

## 1.2 Context and system coverage

The MeerKAT telescope array is composed of 64 Receptors, each consisting of a steerable dish antenna, a set of radio receivers and a set of associated digitisers. The signal is intercepted by an offset Gregorian antenna (Figure 1) after which the receiver converts the electromagnetic wave to electrical signals which is then amplified by cryogenically cooled LNAs before being fed into the appropriate digitiser where the signal gets digitised.

The MeerKAT telescope is required to receive and process four frequency bands: L-, UHF-, S- band and band 5b. The receivers are located in a remotely movable antenna positioner.

The digitised radio signals are then transported over the array fibre network back to the central on-site data centre at the Karoo Array Processor Building where they undergo various stages of processing (correlation, beam forming and science processing). The telescope array is controlled and monitored from a number of remote locations, with the main control operations centre located in Cape Town.

An overview of the signal path of the telescope from the dish to the KAPB is given in Figure 2.



Figure 1 - MeerKAT Receptor.

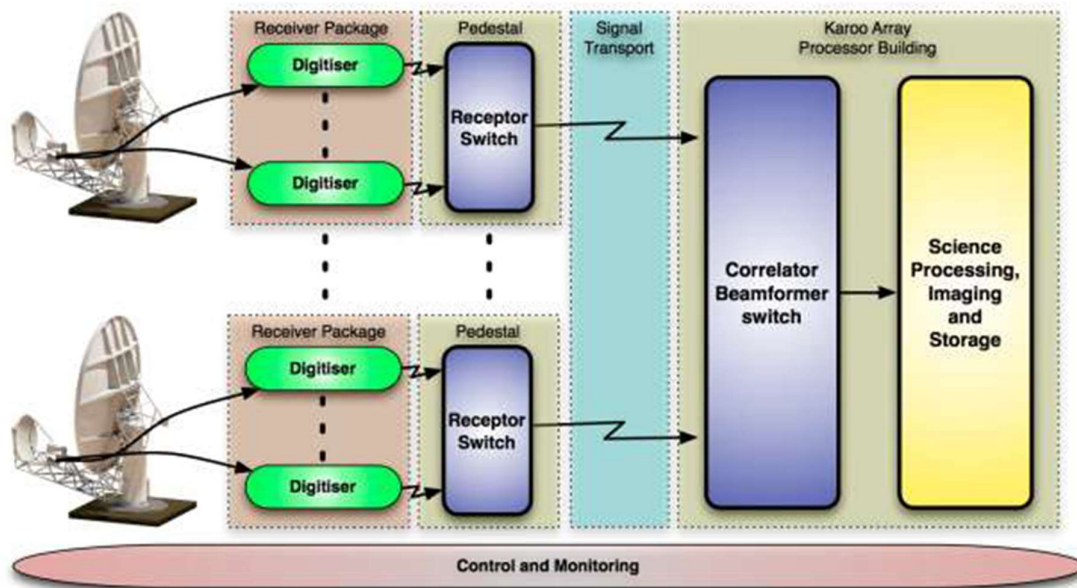


Figure 2 - Flow-chart of the signal path of the Meerkat radio telescope.

### 1.3 Conventions, Definitions, Abbreviations and Acronyms

In this document the following conventions apply:

**May:** The word “may” in the text expresses a permissible practice or action. It does not express a requirement of the specification.

**Must:** The word “must” in the text is used for legislative or regulatory requirements with which both the Purchaser and Vendor shall comply. It is not used to express a requirement.

**Shall:** The word “shall” in the text expresses a mandatory requirement. Departure from such a requirement is not permissible without formal agreement between the Vendor and the Purchaser.

**Should:** The word “should” in the text expresses a recommendation or a nice to have feature.

**Will:** The word “will” in the text expresses a provision or service by the Purchaser or an intention by the purchaser in connection with the requirement. The Vendor is implicitly authorised to rely on such service or intention.

The requirements (listed in Section 4) are identified with a tag following the format [MKT-B5R-SYS-NNNN] where NNNN is a unique progress number grouped for different categories of requirements from functional to operational.

In addition to the requirements, there are some recommendations (listed in Section 5) that are not mandatory and are identified with a tag following the format [MKT-B5R-XXX-NNNN], where XXX indicates the element of the receiver to which the recommendation applies (see Table 1) and NNNN is a unique progress number.

Abbreviation	Full title
PFS	Passive Feed System
LNA	Low Noise Amplifiers
CRY	Cryo-chamber and cold-head
NOD	Noise Diode
RFS	Radio-Frequency Warm Section
RXC	Receiver Controller
RSF	Receiver Support Frame

Table 1 - Abbreviations used for the main elements constituting the receiver. The recommendations in Section 5 refer to some of these elements.

Throughout the document, in addition to the abbreviation indicated in Table 1, the acronyms expressed in Table 2 are used.

Abbreviation	Meaning
AD	Applicable Document
AFN	Array Fibre Network
EM	Electromagnetic
EMI	Electromagnetic interference
ESD	Electrostatic discharge
HW	Hardware
ICD	Interface Control Document
INAF	Istituto Nazionale di AstroFisica
KAPB	Karoo Array Processor Building
LPZ	Lightning Protection Zone
MMDT	Mean Maintenance Down-Time
MTBF	Mean Time Between Failures
N/A	Not Applicable
OMT	OrthoMode Transducer
PI	Principal Investigator
RAMS	Reliability, Availability, Maintainability and Safety
RD	Reference Document
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Root Mean Square
RSS	Root Sum of Squares
RSC	Receiver Systems Controller
SE	System Engineer
SKA	Square Kilometre Array
SKAO	Square Kilometre Array Observatory
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
Trx	Receiver noise temperature
Tsys	System noise temperature
UHF	Ultra High Frequency

Table 2 - List of acronyms to be added to the abbreviations defined in Table 1.

## 1.4. References

### 1.4.1 Applicable Documents

The following documents, of the exact version shown, form part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the content of this document, the content of the applicable document shall be considered as superseding this document.

**AD0** High level interface definition document for the Band 5B Receiver, Document number: M1120-0063-001. Current revision: Rev 1.

Document AD0 is composed of 12 annexes. All of them must be considered applicable documents. Throughout this technical specifications document, only AD0 will be referred to. However, relevant information is addressed in the annexes of AD0.

### 1.4.2 Reference Documents

**RD1** SKA RFI/EMC STANDARD, Document number SKA-TEL-SKO-0000202. Current revision: 04.

**RD2** SKA SYSTEM EMI/EMC CONTROL PLAN FOR PROCUREMENT AND MANUFACTURING PHASE, Document number: SKA-TEL-SKO-0001032. Current revision: 01.

The documents RD1 and RD2 are the property of SKAO and may only be used for the purpose of the tender in question.



## 2. General Overview

### 2.1. System Environment and Boundaries

The receivers shall receive the EM signals in band 5b from the MeerKAT reflector antenna and shall output two signals (corresponding to two linear polarisations) duly amplified. The receiver shall operate in the secondary focus of the MeerKAT optics.

The receivers shall be mechanically hosted on the MeerKAT indexer and shall receive electrical power from the dish system. Furthermore, the receivers shall monitor internal parameters and shall be remotely controlled by the Receiver Systems Controller of MeerKAT.

The receivers shall operate at cryogenic temperature and some components shall be temperature stabilised to achieve the specified performance.

RFI is one of the biggest risks to the Meerkat radio telescopes and for this reason very strict requirements have been imposed for equipment operating at the site. The process to manage RFI compliance of equipment (for instance EMC control plan, Certificate of Conformance and EMC specialist) is described in RD1 and RD2. Contractor must make sure that they understand this process and adhere to the workflow described in these documents.

### 2.2. Architecture Description

Overall, the architecture of each receiver shall be composed of a chain of microwave components mainly consisting of a passive feed-system (circular horn antenna, marker coupler and ortho-mode transducer), two low noise amplifiers (one for each polarisation) and a warm section for further RF conditioning of the signals.

The passive components and the two LNAs of the front-end shall be inserted in a cryogenic environment operating at the physical temperature of approximately 20 and 77 kelvin to ensure the desired noise temperature performance.

More in detail, the architecture description of each receiver is composed of the elements (also called subsystems) described in Table 3, while Figure 3 graphically illustrates the same architecture.

Full title	Description
------------	-------------

<b>Passive Feed System (PFS)</b>	This subsystem shall be composed of a circular corrugated horn, a coupler for the mark injection and a waveguide OMT. These components shall be integrated in the cryo-chamber such that their physical temperature is as low as possible to reduce their contribution to the receiver noise temperature. Furthermore, the passive components shall be connected to each other to transport the RF signals from the feed-horn up to the next stage of the receiving chain (LNA).
<b>Low Noise Amplifiers (LNA)</b>	Two cryogenic amplifiers for each linear polarisation with coaxial connectors / waveguides for RF input/output ports able to ensure the required receiver noise temperature and gain. The amplifiers must be designed to operate at physical temperatures around 15-20 kelvin.
<b>Cryo-chamber and cold-head (CRY)</b>	A cryo-chamber able to operate in vacuum conditions and at a minimum physical temperature of approximately 20 kelvin thanks to a two-stage cold-head working with the Gifford-McMahon Refrigeration Cycle using high pressure helium gas. The cryo-chamber shall host and cool down all the components of the PFS and the two LNAs, their connections for the RF signals transmission and the mechanical supports of each component. The cryo-chamber shall include the following additional functionalities: i) an external RF-transparent vacuum window to maintain the vacuum level without attenuating the incident electromagnetic wave; ii) the electrical feed-through between the inner and the outer of the chamber, namely for the output of two RF signals and for the monitoring and control commands; iii) a vacuum valve to be connected to the vacuum manifold already in place on the MeerKAT indexer; iv) the copper thermal plumbing with radiation shielding and multilayer insulation; v) the mounting plates for the warm RF electronics (namely NOD and RFS) inside the cryostat.
<b>Noise Diode (NOD)</b>	Subsystem composed by a broad-band noise source for injecting the calibration mark into the throat of the feed-horn via a weakly coupled waveguide probe. The noise calibration signal shall be automatically switched on and off based on an external command. This subsystem must be temperature controlled (at room temperature) and located inside the cryo-chamber.
<b>Radio-Frequency Warm Section (RFS)</b>	Printed circuit board hosting RF components (amplifier, step attenuators and slope compensating amplifier) installed in a machined aluminium enclosure and temperature stabilised. This section is needed to reach the overall required performance of the output RF signals before their injection to the digitizer. A band-pass filter in front of the second amplifier could be requested at a later stage in case of evidence of strong RFI signals. This subsystem must be temperature controlled (at room temperature) and located inside the cryo-chamber.
<b>Receiver Controller (RXC)</b>	RFI-tight enclosure housing the unit's power supplies and monitoring and control electronics. This unit shall be located at the external rear of the cryostat and shall be responsible for the following functionalities as a

	minimum: bias and control of the LNA; switching of the noise diode; switching of the vacuum pump; control of vacuum valves; switching of the cold-head; produce all relevant power supplies; monitoring of internal temperatures; control the heater functionality for maintaining temperature of the LNAs; temperature stabilisation control of RFS and NOD. The RXC shall communicate with the Meerkat Receiver Systems Controller (RSC).
<b>Receiver Support Frame (RSF)</b>	Mechanical support of the receiver to be mounted on the dish indexer. The support of the receiver on the feed indexer shall ensure that the feed horn phase reference point coincides with the secondary focus of the MeerKAT reflector antenna.

Table 3 - System architecture. Description of the main elements constituting the receiver.

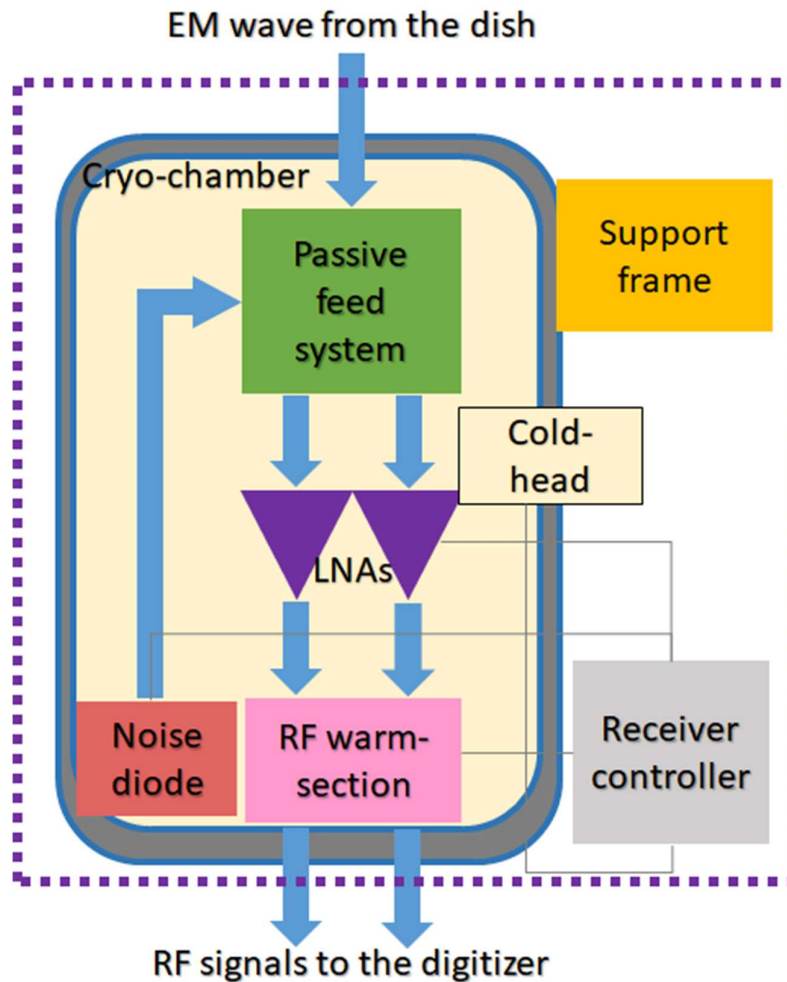


Figure 3 - System architecture. The blue arrows indicate the radio frequency signals as received from the astronomical observation and conditioned by the analogue receiving chain, while the grey lines refer to the power supply and monitor/control signals.

### 2.3. Interfaces Description

The supplier must ensure the compatibility of the receiver with the already existing external components, which are functional to the receiver operation. The document AD0 captures the characteristics and first level details of the major interfaces for the band 5b receiver. This document only serves as input of the interfaces in support of the tender for the receiver and is not an interface control document (ICD). Detailed ICDs will be developed during the formal systems engineering activities for this project.

The operational external interfaces of the receiver are described in Table 4 and graphically represented in Figures 4 and 5. The technical details of the interfaces are given in AD0 and its annexes.

Type of interface	Description	Information
<b>Mechanical</b>	Support of the receiver on the feed indexer	The supply of the band 5b receiver shall include the mechanical support of the receiver to the feed indexer. The mounting system of the support shall be mechanically compatible with the indexer (see also Figure 6).
<b>Cryogenics</b>	High pressure helium supply and return	The band 5b cryostat to be supplied within this tender shall share, with the other receivers installed in the feed indexer, a common helium supply system with a single helium compressor located at the antenna turn head, with helium supply lines routed to the indexer. The existing compressor (not part of the tender supply) has the capacity to keep three cryostats cold simultaneously. The winner of the tender must ensure that the cold-head installed in the band 5b receiver is compatible with the existing compressor: M500 air-cooled compressor from Trillium. Furthermore, the supply of the flexible helium pipes connecting the manifolds in the feed indexer to the cold-head of the receiver are under the responsibility of the winner of the tender.
<b>Vacuum</b>	Vacuum line	A vacuum pump (not part of the tender supply) is located on the indexer with vacuum lines to all cryostats and is only turned on if one of the cryostat vacuums needs to be evacuated. The supply of all the

		vacuum connections between the vacuum pump and the band 5b receiver are under the responsibility of the winner of the tender.
<b>Electrical</b>	Primary power	The distribution of the electrical power (voltage 230 VAC $\pm$ 4% and frequency 50Hz $\pm$ 1%) to the band 5b receiver is done from the Antenna Positioner. Cabling connecting the power distributor and the receiver is not part of the tender supply.
<b>Radio Frequency</b>	Incoming electromagnetic wave	The feed horn shall be designed for an optimal coupling with the optics of the Meerkat dish (see Figure 7).
	Two conditioned voltage signals at the output ports of the receiver	The two conditioned RF signals at the output ports of the receiver shall be delivered to the digitizer with a well defined power level. The supply of the coaxial cables connecting the receiver to the digitizer are outside the responsibility of the winner of the tender.
<b>Communication</b>	Control and monitoring signals	The Meerkat Receiver Systems Controller (RSC) shall communicate with the band 5b receiver to control and monitor the receiver parameters and to ensure its functionality. Cabling connecting the RSC and the receiver is not part of the tender supply. Signals of control and monitoring are transferred by the same optical fibre cable containing also the noise diode control.
<b>Noise diode</b>	Noise diode control signal	The noise diode control signal is generated by the digitizer. It is used to synchronously control the noise diode with respect to the digitizer spectrometer. This signal is injected to the receiver using a fibre optic interface. Fibre optic cable connecting the digitizer and the receiver is not part of the tender supply. The noise diode control is sent to the receiver by using the same fibre optical as for the control and monitoring signals.

Table 4 - Description of the main interfaces between the receiver and the MeerKAT Receptor.

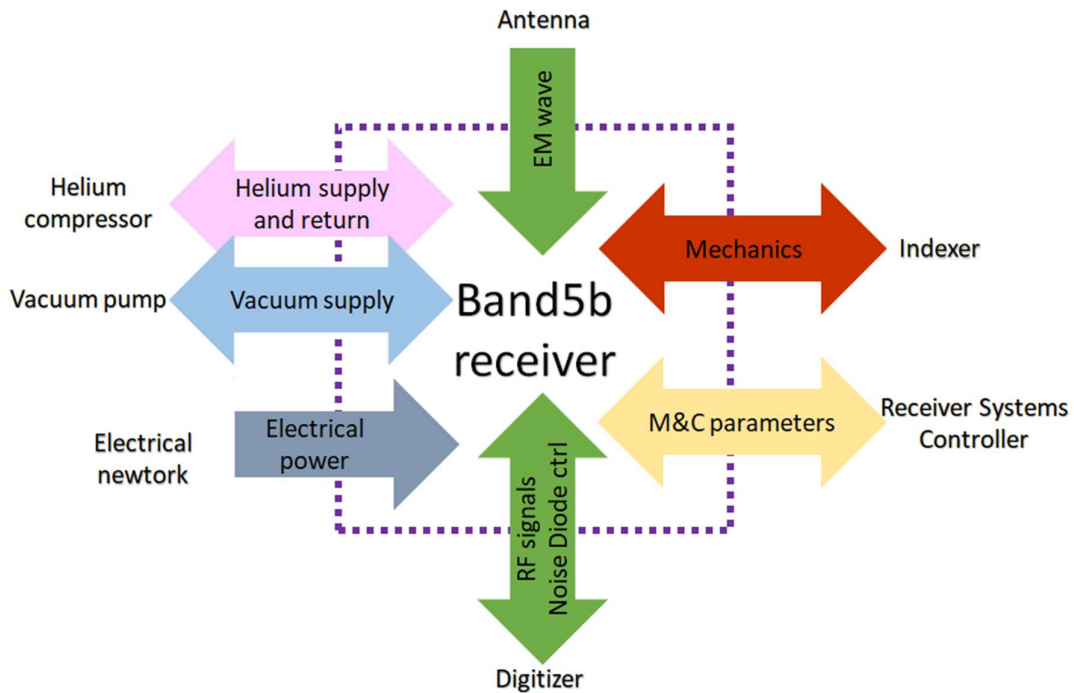


Figure 4 - External interfaces.

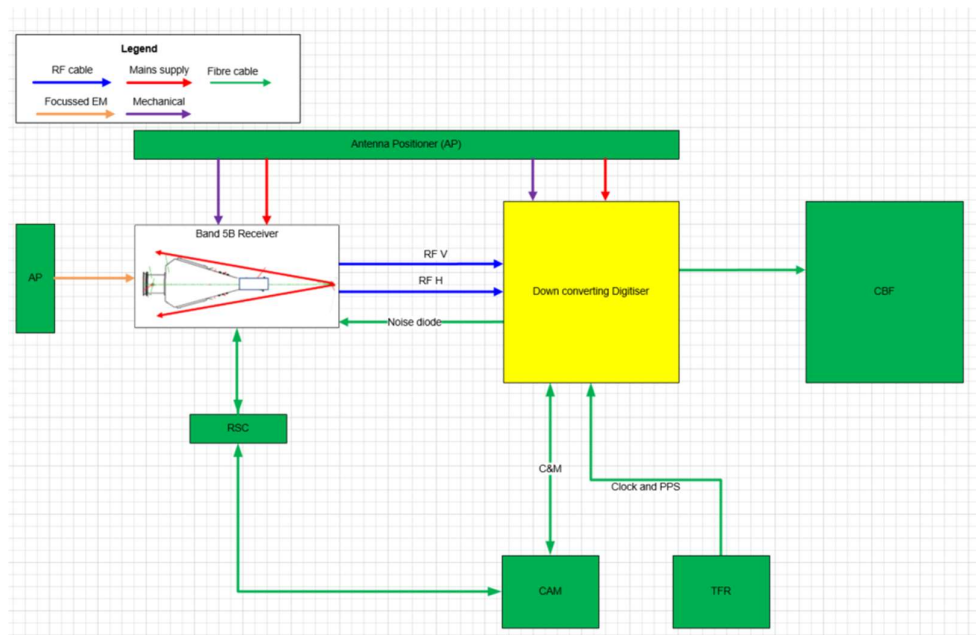


Figure 5 - Diagram with the context of band 5b receiver.

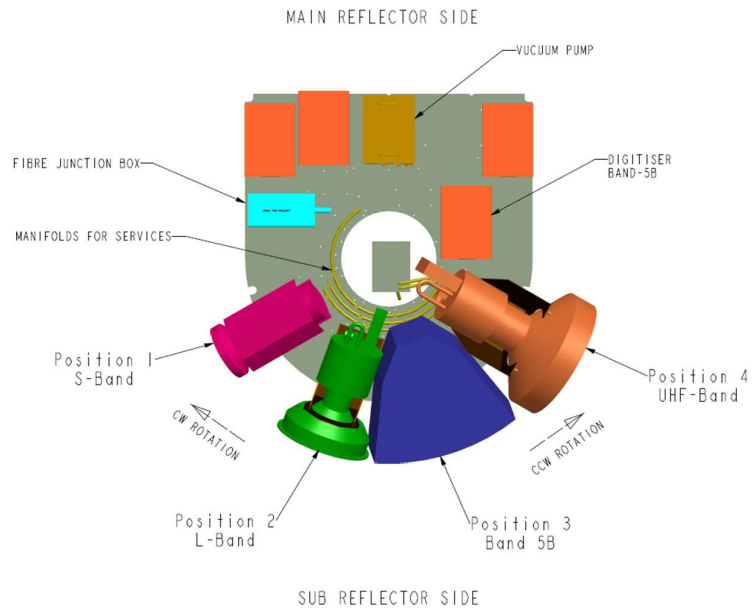


Figure 6 - Drawing of the MeerKAT feed indexer. The blue block represents the volume available for the band 5b receiver.

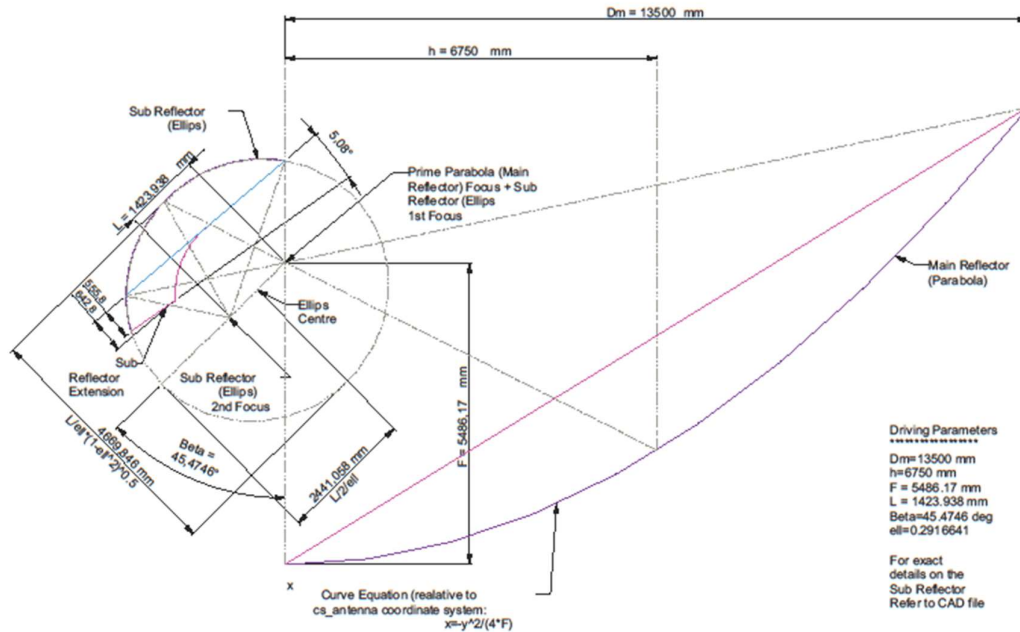


Figure 7 - Drawing of the design baseline MeerKAT optical system. This is only for information and does not reflect the actual dimensions of the mirrors. Refer to ICD documents for actual dimensions.

## 2.4. System Functionality

The following primary functions shall be implemented by the receiver:

- Intercepting the EM fields focussed by the reflector system to achieve the specified performance.
- Converting the electromagnetic signal to an RF signal and amplifying it to the level required by the digitizer while adding as little noise as possible.
- Adding a switched calibration signal.
- Reporting the monitoring data and remotely controlling the operations of the receiver through the Receiver System Controller.
- Matching all the interfaces with the external MeerKAT infrastructures.

## 2.5. Assumptions

The system level requirements (MKT-B5R-SYS-NNNN) are mandatory, while the recommendations at element level have lower priority and suggest possible solutions to



reach the system level requirements. As long as the system level requirements are met, different implementations at element level with respect to the INAF suggestions are acceptable. Furthermore, INAF does not take any responsibility if the system level requirements are not reached despite the fact that the recommendations have been followed.

### 3. Environmental Conditions

The Table 5 lists all following environmental conditions which are then referred to by the operational requirements:

- Deployed conditions
- Operational conditions:
  - Precision Operating conditions
  - Standard Operating conditions
  - Degraded Operating conditions
- Survival conditions
- Storage conditions
- Transportation conditions

Term Definition	Conditions
Deployed Conditions	<p>The Deployed (Environmental) Conditions for the receivers installed at the Meerkat dishes (non weather protected) are defined by ETSI 300 019-1-4 Class 4.2H (IEC 60721-3-4 Classes 4K4H/4Z1/4Z5/4Z7/4B2/4C2/4S2/4M5) with the following tailoring:</p> <p>a) Climatic Conditions:</p> <ul style="list-style-type: none"> <li>- Air Temperature:               <ul style="list-style-type: none"> <li>- Minimum Air Temperature: -5 degC</li> <li>- Maximum Air Temperature: +40 degC</li> </ul> </li> <li>- Maximum rate of change of air temperature: 5.0 degC / 10 min</li> <li>- Solar Radiation:               <ul style="list-style-type: none"> <li>- Average daily: 451 Watt/m^2</li> <li>- Peak: 1120 Watt/m^2</li> </ul> </li> <li>- Wind (at a height of 10m above ground level and a nominal air density of 1.05 kg/m^3 at 20 degC):               <ul style="list-style-type: none"> <li>- Average wind speed: 4.2 m/s</li> <li>- Peak wind speed: 20 m/s (operating)</li> <li>- Peak survival wind speed: 44.4 m/s (Dish in stow position)</li> </ul> </li> <li>- Dew: Yes</li> <li>- Snowfall of up to 20 mm with a density of 130 kg/m^3</li> <li>- Hail with impact energy of 11J (Typically tested by 38mm ice ball at 27.4m/s)</li> </ul> <p>b) Chemically active substances</p> <ul style="list-style-type: none"> <li>- IEC 60721-3-4 Class 4C1</li> </ul> <p>c) Mechanically active substances</p> <ul style="list-style-type: none"> <li>- 98% of lifetime: IEC 60721-3-4 Class 4S2</li> </ul>

	<ul style="list-style-type: none"> <li>- 2% of lifetime: IEC 60721-3-4 Class 4S3</li> <li>d) Mechanical conditions <ul style="list-style-type: none"> <li>- IEC 60721-3-4 Class 4M1</li> </ul> </li> <li>e) Earthquake conditions <ul style="list-style-type: none"> <li>- Maximum peak ground acceleration of 1 m/s<sup>2</sup>, Seismic Zone 1 as defined in IEC 60721-2-6</li> </ul> </li> <li>f) Lightning conditions with the following ground flash densities are expected: <ul style="list-style-type: none"> <li>- SKA1 Mid site: 1-3 strikes per km<sup>2</sup> per year</li> </ul> </li> <li>g) Height above sea level: <ul style="list-style-type: none"> <li>- SKA1 Mid site: 900 m - 1100 m</li> </ul> </li> </ul> <p>Notes:</p> <ul style="list-style-type: none"> <li>- Tailoring is based on Environmental Conditions for the SKA1 Mid Site in South Africa [301-000000-009]</li> <li>- Further tailoring is employed for specific deployed Operating Conditions.</li> </ul>
Operational conditions	For equipment that is installed in the un-protected environment this refers to the combination of Precision, Standard and Degraded Operating Conditions.
Precision Operating Conditions	<p>The Precision Operating Conditions are defined as the Deployed Conditions with the following alterations:</p> <ul style="list-style-type: none"> <li>a) Air Temperature <ul style="list-style-type: none"> <li>- Minimum Air Temperature: -5 degC</li> <li>- Maximum Air Temperature: 40 degC</li> </ul> </li> <li>b) Maximum rate of change of air temperature: 3.0degC/1000Sec</li> <li>c) Wind <ul style="list-style-type: none"> <li>- Maximum average wind speed (1000Sec average): 5m/s, AND</li> <li>- Maximum difference between the 95th percentile instantaneous wind and the average wind speed, over 10 min interval: 3×0.7m/s</li> </ul> </li> <li>d) No rain, ice, hail, snow, frost or dew (These conditions are applicable with regards to operation and functionality, but the impact on the performance is not applicable.)</li> <li>e) No earthquake</li> <li>f) No lightning</li> </ul> <p>Note:</p> <ul style="list-style-type: none"> <li>- The Precision Operating Conditions occur for ~59% of the system life.</li> <li>- For the purpose of Dish performance these conditions occur simultaneously, but the effect on performance is added in RSS.</li> </ul>
Standard Operating Conditions	<p>The Standard Operating Conditions are defined as the Deployed Conditions with the following alterations:</p> <ul style="list-style-type: none"> <li>a) Air Temperature <ul style="list-style-type: none"> <li>- Minimum Air Temperature: -5 degC</li> <li>- Maximum Air Temperature: 40 degC</li> </ul> </li> <li>b) Maximum rate of change of air temperature: 3degC/1000sec</li> <li>c) Wind <ul style="list-style-type: none"> <li>- Maximum average wind speed (1000sec average): 7m/s, AND</li> <li>- Maximum difference between the 95th percentile instantaneous wind and the average wind speed, over 10 min interval: 3×1.2m/s</li> </ul> </li> </ul>

	<p>d) No rain, ice, hail, snow, frost or dew (These conditions are applicable with regards to operation and functionality, but the impact on the performance is not applicable.)</p> <p>e) No earthquake</p> <p>f) No lightning</p> <p>Note:</p> <ul style="list-style-type: none"><li>- The Standard Operating Conditions occur for ~27% of the system life.</li><li>- Dish performance is to be evaluated as if these conditions occur simultaneously, with contributions added in RSS.</li></ul>
Degraded Operating Conditions	<p>The Degraded Operating Conditions are defined as the Deployed Conditions with the following alterations:</p> <p>a) Air Temperature</p> <ul style="list-style-type: none"><li>- Minimum Air Temperature: -5 degC</li><li>- Maximum Air Temperature: 40 degC</li></ul> <p>b) Maximum rate of change of air temperature: 4.5 degC/1000sec</p> <p>c) Wind</p> <ul style="list-style-type: none"><li>- Maximum average wind speed (1000 sec average): 10m/s</li></ul> <p>AND</p> <ul style="list-style-type: none"><li>- Maximum difference between the 95th percentile instantaneous wind and the average wind speed, over 10 min interval: 3×1.5m/s</li></ul> <p>d) No rain, ice, hail, snow, frost or dew (These conditions are applicable with regards to operation and functionality, but the impact on the performance is not applicable.)</p> <p>e) No earthquake</p> <p>f) No lightning</p> <p>Note:</p> <ul style="list-style-type: none"><li>- The Degraded Operating Conditions occur for ~12% of the system life.</li><li>- Dish performance is to be evaluated as if these conditions occur simultaneously, with contributions added in RSS.</li></ul>
Survival Conditions	<p>The Survival Conditions are defined as all the extremes of the Deployed Conditions.</p> <p>Note:</p> <ul style="list-style-type: none"><li>- It is not expected that the extreme conditions will occur simultaneously in time.</li><li>- The survival air temperature conditions occur ~ 0.1% of the system life.</li><li>- The probability of the survival wind conditions is ~ 0.01% over the system life.</li></ul>

Storage conditions	<p>The Storage Conditions for equipment to be stored in a weather protected facility are defined by ETSI 300 019-1-1 Class 1.1 as tailored (IEC 60721-3-1 Classes 1K3/1Z1/1B2/1C2/1S2/1M2):</p> <ul style="list-style-type: none"> <li>- Climatic conditions 1K3/1Z2 changed to 1K3/1Z1 (i.e. no heat radiation from sources other than the sun)</li> <li>- Biological Conditions changed from 1B1 to 1B2</li> </ul> <p>Note:</p> <ul style="list-style-type: none"> <li>- Tailoring is based on Environmental Conditions for the SKA1 Mid Site in South Africa [301-000000-009]</li> <li>- The definition for Storage Conditions for equipment to be stored in a non weather protected facility, has been removed.</li> </ul>
Transportation Conditions	<p>The Transportation Conditions are defined by ETSI 300 019-1-2 Class 2.2 as tailored (IEC 60721-3-2 Classes 2K5H/2B2/2C2/2S2(2S3)/2M3):</p> <p>a) Climatic Conditions ETSI Class 2.2 changed from 2K3 to 2K5H and:</p> <ul style="list-style-type: none"> <li>- Minimum Air Temperature: -5degC</li> <li>- Maximum Air Temperature, unventilated: 70degC</li> <li>- Maximum Air Temperature, ventilated: 40degC</li> <li>- Change of temperature (air/air): -5/+30 degC</li> <li>- Change of temperature (air/water): +40/+5 degC</li> <li>- Relative Humidity High, combined with rapid temperature changes: 95%, -5/+30 degC</li> <li>- Absolute Humidity combined with rapid temperature changes : air/air at high water content: 60g/m3, +70/+15 degC</li> <li>- Low air pressure: 70 kPa</li> <li>- Change of air pressure: No</li> <li>- Movement of surrounding air: 20 m/s</li> <li>- Water from other sources than rain: 1m/s (Splashing for short duration only - transport by sea on open ship's deck is excluded)</li> </ul> <p>b) Mechanically active substances.</p> <ul style="list-style-type: none"> <li>- IEC 60721-3-2 Class 2S3 additional to 2S2</li> </ul> <p>c) Mechanical conditions.</p> <ul style="list-style-type: none"> <li>- IEC 60721-3-2 Class 2M changed to 2M2 for transport on tar roads and 2M3 for transport on gravel roads and:</li> <li>- Free fall based on IEC 60721-3-2 Class 2M1</li> <li>- Toppling based on IEC 60721-3-2 Class 2M1</li> <li>- Rolling, pitching based on IEC 60721-3-2 Class 2M1 (None)</li> <li>- Static load based on IEC 60721-3-2 Class 2M1, but limited to the induced load from stacking the specific equipment to a height of 2.3m</li> </ul> <p>Note:</p> <ul style="list-style-type: none"> <li>- Tailoring is based on Environmental Conditions for the SKA1 Mid Site in South Africa [301-000000-009]</li> </ul>

Table 5 - Description of the different environmental conditions at the MeerKAT site.

## 4. System Requirements

The System requirements are classified according to the following categories:

- Functional (Table 6)
- Operational (Table 7)
- Interface (Table 8)
- Quality (Table 9)

The Tables 6 to 8 must be interpreted according to the following format:

ID\_requirement = univocal identifier of the requirement

Requirement = subject of the requirement

Value = target value that shall be satisfied by the system

Note = Additional information to the requirement

while Table 9 is structured with the format:

ID\_requirement = univocal identifier of the requirement

Requirement = subject of the requirement

Value/content = target value that shall be satisfied by the system

### 4.1. Functional Requirements

The functional requirements are specified in Table 6.

Requirement_ID	Requirement	Value/Content	Note
<b>Observing and output frequencies</b>			
MKT-B5R-SYS-0001	Input frequency range	[8.3,15.4] GHz	The receiver shall meet all requirements for EM waves in this frequency range
MKT-B5R-SYS-0002	Output frequency range	[8.3,15.4] GHz	The output frequency shall not be converted in any base-band
MKT-B5R-SYS-0003	Instantaneous bandwidth	7.1 GHz	The receiver shall deliver at the two output ports a bandwidth equal to the difference between maximum and minimum frequency
<b>Polarisation and reflector's illumination</b>			
MKT-B5R-SYS-0004	Output polarisation	Two linear polarizations	The receiver shall include a OMT to divide the two linear polarisation and provide two outputs

Requirement_ID	Requirement	Value/Content	Note
MKT-B5R-SYS-0005	Polarisation orientation	Polarisations at $\pm 45^\circ$ to the dish symmetry plane with a maximum rotation $< 5^\circ$	The orthogonal polarisations shall not be rotated more than $\pm 5^\circ$ from the nominal position
MKT-B5R-SYS-0006	Illumination taper at the edge of Meerkat reflector	Gaussian pattern axially symmetric with $-15 \pm 2$ dB (TBC) @ $48.9^\circ$ from boresight direction	The supplier shall conduct an optimization analysis of the illumination taper to reach the maximum aperture efficiency and directivity. The tolerance $\pm 2$ dB (TBC) applies to the taper level across the azimuthal planes of the pattern and the frequency band. The final taper level to be adopted shall be discussed and agreed with the INAF team. A GRASP model of the Meerkat optics will be made available to perform this analysis.
MKT-B5R-SYS-0007	Intrinsic cross polarisation (IXR) level	$\geq 15$ dB within the $-3$ dB contour of the beam given by the coupling between receiver and dishes	This requirement has to be verified by analyses of the feed patterns while illuminating the reflector by using the GRASP model
MKT-B5R-SYS-0008	Phase centre position	The mechanics of the receiver shall be designed to locate the feed phase centre to the antenna secondary focus with a precision of better than 1 mm	The phase centre position is the defined fixed point of the feed which shall be positioned to be coincident with the reflector focus point. Neither active nor manual focus adjustment mechanism is requested in the receiver
<b>Amplification and other RF performance</b>			
MKT-B5R-SYS-0009	Overall gain and flatness	$56 \pm 3$ dB	The overall (band-averaged) gain is given by the combination of individual gains of active stages and losses of

Requirement_ID	Requirement	Value/Content	Note
			passive stages. The input signal is assumed to have a nominal flat power spectral density at the LNA input of -188 dBm/Hz
MKT-B5R-SYS-0010	Receiver noise temperature, Trx	$< 10.6 + 0.633 \cdot (\nu - 8.41)$	The receiver noise temperature shall be constrained by the equation where $\nu$ is a frequency expressed in GHz and variable over the frequency range given in MKT-B5R-SYS-0001
MKT-B5R-SYS-0011	Output power spectral flatness	$\leq 2$ dBpp across any 2.5 GHz interval	Variation of the magnitude of the output spectrum across the specified frequency range with the feed looking at the cold sky
MKT-B5R-SYS-0012	Output return loss	$< -16$ dB	This requirement is based on a 50 Ohm characteristic impedance
MKT-B5R-SYS-0013	Saturated power	$\leq 10$ dBm	Referred to the output port
MKT-B5R-SYS-0014	Third-order intercept point	$\geq -43$ dBm	Referred to the input port
MKT-B5R-SYS-0015	Survival input power levels	$\geq -6$ dBm for 10 sec $\geq +5$ dBm for 1 sec	The receiver shall survive an input signals applied for a certain period of time at the input of each LNA with no permanent degradation to performance
MKT-B5R-SYS-0016	Gain stability (fluctuations)	$\leq 0.08\%$ RMS over 5 s, when averaged over the central 500 MHz of the band and sampled with 20 ms intervals	The gain stability shall be measured between the receiver input and output ports
MKT-B5R-SYS-0017	Phase stability peak to peak	$\leq 1^\circ$ peak to peak over 20 minutes when sampled with 5 s intervals	The phase stability shall be measured between the receiver input and output ports

Requirement_ID	Requirement	Value/Content	Note
MKT-B5R-SYS-0018	Phase stability RMS	$\leq 0.5^\circ$ RMS over 20 minutes, after subtracting a linear fit through the data points of the 20 minutes, when sampled with 5 s intervals	The phase stability shall be measured between the receiver input and output ports
MKT-B5R-SYS-0019	Interferences rejection	A band pass filter between output of LNA and input of the 2nd stage amplifier could be requested at a later stage	A provision for adding a band pass filter is made in case of evidence of strong interference potentially affecting the linear behaviour of the second stage amplifier
<b>Noise calibration</b>			
MKT-B5R-SYS-0020	Noise calibration level	5% - 13% of Tsys	Power spectral density averaged over any 1 MHz bandwidth across the specified frequency range and with Tsys computed for cold sky at the lowest specified elevation angle. It is noted that Tsys includes the receiver noise temperature plus the sky/ground contribution. Information on Tsys will be made available at a later time by INAF. The final noise calibration level to be adopted shall be discussed and agreed with the INAF team.
MKT-B5R-SYS-0021	Noise calibration injection point	At the earliest possible point preceding the LNA	A switchable, wideband calibration signal shall be injected into both polarisation channels (i.e. one signal into both channels)
MKT-B5R-SYS-0022	Noise calibration signal stability	$\leq 0.04\%$ over 30 minute intervals integrated over 500 MHz and 500 ms	Standard deviation of the power of the calibration signal, referenced to the input of the LNA



Requirement_ID	Requirement	Value/Content	Note
MKT-B5R-SYS-0023	Noise calibration phase imbalance stability	$< 0.3^\circ$ RMS over the frequency range	Stability of the phase difference with which the calibration noise signal is injected into the two RF signal paths
MKT-B5R-SYS-0024	Noise calibration switching response time	$\leq 30$ microsec, with jitter $\leq 70$ ns RMS	Maximum level of the sum of the switch ON and switch OFF times of the calibration signal (measured from the edge of the applied switching signal till the calibration signal reaches 50% of its final value)
<b>Physical Characteristics</b>			
MKT-B5R-SYS-0025	Maximum dimension	The receiver shall not exceed a specific volume available in the indexer	See AD0
MKT-B5R-SYS-0026	Maximum weight	72 kg	See AD0
MKT-B5R-SYS-0027	Power consumption	$< 150$ VA at power factor $\geq 0.5$	Maximum utilisation of primary power
MKT-B5R-SYS-0028	Cryo-head	The cryo-head mounted in the receiver shall be compatible with the Meerkat compressor and with SARAO operational procedures	See AD0
MKT-B5R-SYS-0029	Interconnection characteristics	The receiver shall be connected with external mechanical, RF, power, vacuum, helium, fibre and network interfaces	See AD0
<b>Communication and monitoring</b>			
MKT-B5R-SYS-0030	States and Modes	The receiver shall report its Modes and Power States to the external Meerkat Monitoring and Control system	See AD0
MKT-B5R-SYS-0031	Monitoring and control	The receiver shall monitor and control	See AD0

Requirement_ID	Requirement	Value/Content	Note
		several functional and operational parameters and report their status to the external Meerkat Monitoring and Control system	
MKT-B5R-SYS-0032	Remote support capability	The receiver shall provide an engineering interface that can be accessed remotely for detailed diagnostics and low level control	See AD0
MKT-B5R-SYS-0033	Temperature sensors	At least in four points of the receiver the physical temperature shall be measured	The temperature of the following components shall be measured: i) cryostat body; ii) 1st stage of the cryo-head; iii) OMT; iv) RFS.
<b>Radio Frequency Interference</b>			
MKT-B5R-SYS-0034	Maximum allowed radiation levels	Over the specified frequency band from 50 MHz to 20 GHz, the components of the receiver shall not radiate EMI above: 1) The Spectral Line Threshold Level depicted in Figure 8 and measured in a RBW of 0.001% of centre frequency 2) The Continuum Threshold Level depicted in Figure 8 and measured in a RBW of 1% of centre frequency	A relaxation of 30 dB above 300 MHz shall apply for power radiated by the Calibration Noise Source when activated under command from the receiver. Each receiver delivered to the site must have a RFI certificate of conformance before being delivered to the Meerkat site. It is recommended to perform a RFI qualification in South Africa using the SARAO accredited test facilities. Alternative qualification facilities must be approved by INAF. See also RD1 and RD2
MKT-B5R-SYS-0035	Maximum Allowed Pulsed Radiation Levels	Over the specified frequency band from 50 MHz to 20 GHz, receiver components	Each receiver delivered to the site must have a certificate of conformance

Requirement_ID	Requirement	Value/Content	Note
		shall not radiate pulsed EMI that contaminate more than 5% of 500 ms data blocks with RFI pulses larger than the Pulsed Threshold level depicted in Figure 9 when measured in a 10 MHz resolution bandwidth and 1 $\mu$ s integration time	before being delivered to the Meerkat site. It is recommended to perform a RFI qualification in South Africa using the SARAO accredited test facilities. Alternative qualification facilities must be approved by INAF. See also RD1 and RD2
MKT-B5R-SYS-0036	Maximum Allowed Conducted EMI Levels	Over the specified frequency band from 300 MHz to 20 GHz, receiver components shall not add RF power to the signal chain, referenced at the input to the LNA, above: 1) The Spectral Line Threshold Level depicted in Figure 10 and measured in a RBW of 0.001% of centre frequency, 2) The Continuum Threshold Level depicted in Figure 10 and measured in a RBW of 1% of centre frequency.	RF power from the Calibration Noise Source is excluded. Each receiver delivered to the site must have a certificate of conformance before being delivered to the Meerkat site. It is recommended to perform a RFI qualification in South Africa using the SARAO accredited test facilities. Alternative qualification facilities must be approved by INAF. See also RD1 and RD2

Table 6 - Functional Requirements.

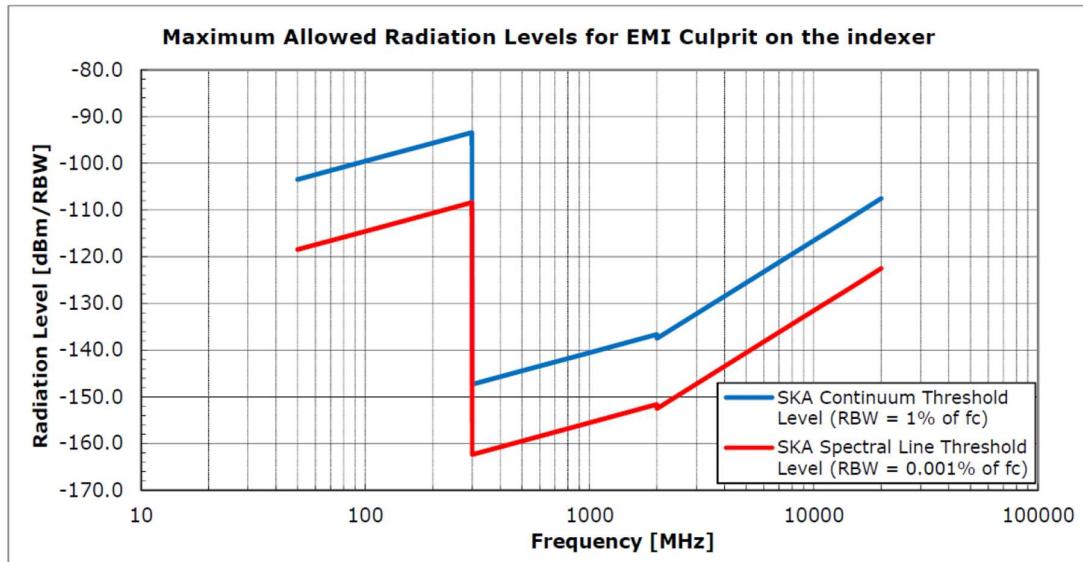


Figure 8 - Maximum Allowed Radiation Levels for MKT-B5R-SYS-0034.

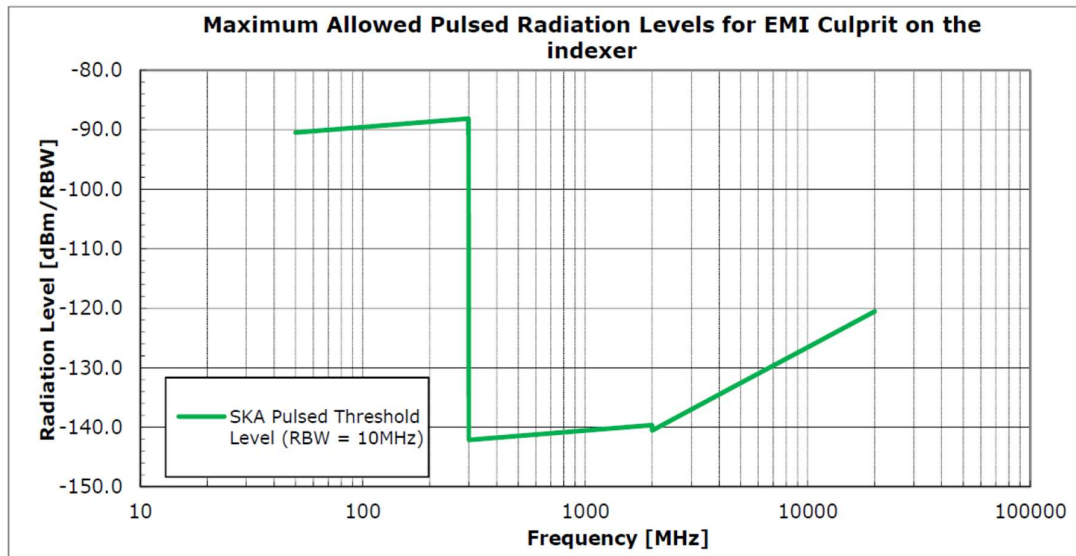


Figure 9 - Maximum Allowed Pulsed Radiation Levels for MKT-B5R-SYS-0035.

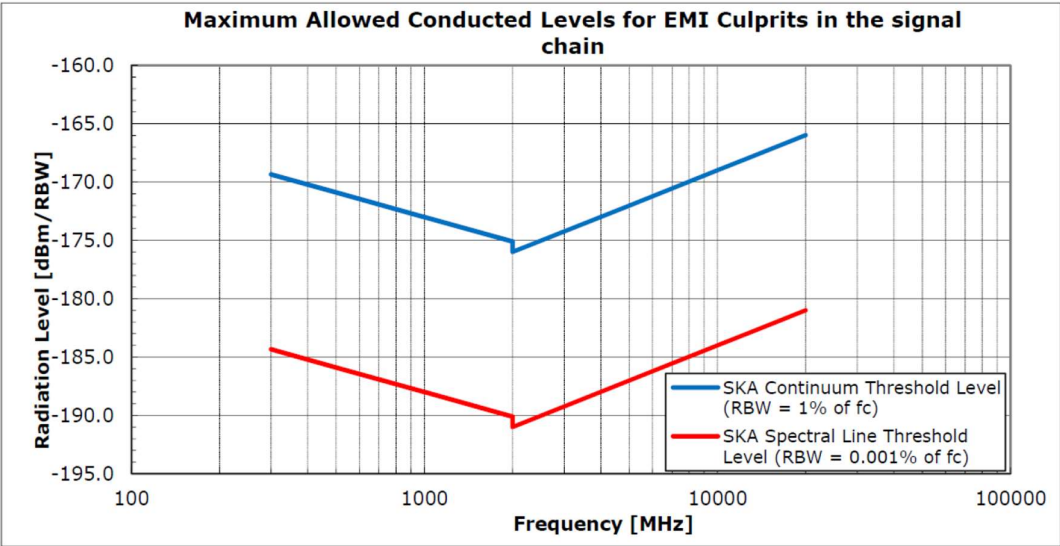


Figure 10 - Maximum Allowed Conducted Levels for MKT-B5R-SYS-0036.

4.2. Operational Requirements

The operation requirements are specified in Table 7.

ID_requirement	Requirement	Value/Content	Note
MKT-B5R-SYS-0100	Durability	The receiver shall survive, without any residual damage or performance degradation, when operated under the Deployed Conditions throughout the Deployed Lifetime	
MKT-B5R-SYS-0101	Endurance	The receiver shall sustain continuous operation, without performance degradation, under the Precision, Standard and Degraded Operating Conditions throughout the required Deployed Lifetime	

ID_requirement	Requirement	Value/Content	Note
MKT-B5R-SYS-0102	Operation	The receiver shall be fully functional when operated under the Precision, Standard and Degraded Operating Conditions throughout the required Deployed Lifetime	
MKT-B5R-SYS-0103	Survival	The receiver shall survive and perform according to the requirements as stated in this specification after being subjected to the Survival Conditions throughout the Deployed Lifetime	During Survival Conditions the system may turn itself off for protection.
MKT-B5R-SYS-0104	Induced Vibration and Shock	The components mounted to dish shall not induce vibration and shock that exceed the levels as defined in AD0	
MKT-B5R-SYS-0105	Vibration and Shock Susceptibility	The components mounted to dish shall perform according to its requirements, as defined in this document, when subjected to the vibration and shock levels as defined in AD0	
MKT-B5R-SYS-0106	Characteristics of Electrical Power Supply to receiver components	The receiver components shall perform according to its requirements, as defined in this document, when supplied with the electrical power with the characteristics as defined in AD0	

ID_requirement	Requirement	Value/Content	Note
MKT-B5R-SYS-0107	No damage due to cooling and heating cycles	The Receiver shall be designed to not sustain any damage as a result of at least five cooling and heating cycles (between ambient to cryo temperatures) per year due to observation seasons scheduled by the MeerKAT telescope	<p>Observation seasons:</p> <p>The helium compressor used on the MeerKAT telescope is not able to supply sufficient helium to cool four receivers concurrently. Observation seasons are therefore introduced which will allow three receivers to be cooled concurrently at a time while the fourth (unused) receiver is disconnected from the compressor using isolation valves. The observation season will be scheduled such that an unused receiver will switch off for a minimum of one month and will be operational for at least two months (TBC) as part of the scheduling of the observation season.</p> <p>Helium isolation valves:</p> <p>Helium isolation valves are installed on the helium interface which will allow unused receivers to be isolated from the helium supply to prevent helium leakage through the unused cryo-head. The supply of these isolation valves are outside the scope of the Receiver contract.</p>
MKT-B5R-SYS-0108	Environmental shield	An environmental shield shall be included as part of the receiver installation.	The purpose of this shield being to protect the receiver and connectors against long term exposure to direct sun as experienced on the MeerKAT site

Table 7 - Operational Requirements.

4.3. External Interface Requirements

The external interface requirements are specified in Table 8.

ID_requirement	Requirement	Value/Content	Note
MKT-B5R-SYS-0200	Receiver to antenna interface	The receiver shall adhere to the requirements given in AD0	Mechanical interface (see Section 2.3)
MKT-B5R-SYS-0201	Receiver to digitizer interface	The receiver shall adhere to the requirements given in AD0	Radio Frequency and Noise Diode interfaces (see Section 2.3)
MKT-B5R-SYS-0202	Receiver to the optics interface	The receiver shall adhere to the requirements given in AD0	Radio Frequency interface (see Section 2.3)
MKT-B5R-SYS-0203	Receiver to the system controller interface	The receiver shall adhere to the requirements given in AD0	Communication interface (see Section 2.3)
MKT-B5R-SYS-0204	Receiver to cryogenic system interface	The receiver shall adhere to the requirements given in AD0	Cryogenics interface (see Section 2.3)
MKT-B5R-SYS-0205	Receiver to vacuum system interface	The receiver shall adhere to the requirements given in AD0	Vacuum interface (see Section 2.3)
MKT-B5R-SYS-0206	Receiver to Primary power	The receiver shall adhere to the requirements given in AD0	Electrical interface (see Section 2.3)

Table 8 - External Interface Requirements.

4.4. Quality Requirements

The quality requirements are specified in Table 9.

ID_requirement	Requirement	Value/Content
Reliability, Availability and Maintainability		
MKT-B5R-SYS-0300	Deployed Lifetime <sup>1</sup>	≥ 10 years

<sup>1</sup> Deployed Lifetime (of an item) is defined as the duration of the time period, commencing at deployment into operational use, during which the item would perform to the specified level of



ID_requirement	Requirement	Value/Content
MKT-B5R-SYS-0301	Mean Maintenance Down-Time	< 2.5 hours (note that MMDT is defined as only the time technicians spent at the antenna)
MKT-B5R-SYS-0302	Mean Time Between Maintenance	The receiver shall have a mean time between unscheduled corrective maintenance of 17 months, with once a year scheduled maintenance (note: effectively this defines the minimum MTBF, provided that the annual preventative maintenance is performed)
<b>Repair and replacement</b>		
MKT-B5R-SYS-0310	Access	Equipment shall be designed to use standard tools for accessing, removing and replacing the items, and access to equipment and components that require specialised tools shall be minimised
MKT-B5R-SYS-0311	Component removal	Modules and components shall be mounted such that where practicable, removal of any single item will not require the removal of other items (component stacking to be avoided where possible)
MKT-B5R-SYS-0312	Intermediate Level Maintenance (ILM) Repair	items identified as ILM Spare Items, shall require a minimum of tuning, calibration, aligning or other actions. Where alignment, calibration or tuning is required, a deterministic procedure for such actions shall be contained in the support publications
MKT-B5R-SYS-0313	Maintenance provisions	Repairable items shall be designed to include maintenance provisions such as test points, accessibility, and plug-in components where practicable
MKT-B5R-SYS-0314	Modular design	The components shall be designed to be modular where practicable, to enable easy removal and replacement of faulty line replaceable units.
MKT-B5R-SYS-0315	Module mounting guides	Modules and components shall incorporate mounting guides and location where practicable to facilitate module mounting
MKT-B5R-SYS-0316	Mounting preclusion	Modules and components shall incorporate provisions for the preclusion of mounting the wrong module shall be provided (key coding of connectors etc.)
MKT-B5R-SYS-0317	Organisational Level Maintenance	OLM Spares Items shall be interchangeable with items of the same Part Number and Version with no

performance, when subjected to the normal expected use and provided relevant agreed maintenance procedures are executed as prescribed by the manufacturer. During this lifetime, the manufacturer would provide access to support in terms of maintenance and repair needs and during which time, when subjected to the normal expected use and provided maintenance is executed as prescribed, the item will not have to be replaced due to it becoming irreparable through normal wear and tear. The design must minimise requirements for maintenance where possible.

ID_requirement	Requirement	Value/Content
	(OLM) interchangeability	calibration, tuning or special alignment where practicable
MKT-B5R-SYS-0318	Stand-off and handles	Modules and components shall incorporate Stand-offs and handles to protect system components from damage during shop maintenance
<b>Product marking</b>		
MKT-B5R-SYS-0320	Cable Identification	Cables/Harnesses and their connectors shall be labelled to allow identification while installed
MKT-B5R-SYS-0321	Connector Labelling	Component mounted connectors shall be labelled to allow identification during installation and maintenance of the equipment
MKT-B5R-SYS-0322	Controls Labelling	Switches and controls used by operators or technical personnel shall have their functions clearly marked in the English language
MKT-B5R-SYS-0323	Disposable item labelling	Disposable line replaceable units shall be labelled as such
MKT-B5R-SYS-0324	Equipment damage warnings	Modules and components requiring special handling to prevent damage to Items (e.g. electrostatic discharge) shall be clearly marked with warning labels.
MKT-B5R-SYS-0325	Hazard Labelling	Equipment that, when improperly operated or handled, may jeopardise the safety of personnel or result in a hazardous situation, shall be clearly marked to such effect
MKT-B5R-SYS-0326	Label content	Modules shall be labelled with the following information: <ul style="list-style-type: none"> <li>• Product Supplier Name</li> <li>• Product Name (Supplied by SE for fabricated or subcontracted items)</li> <li>• Product Part Number (Supplied by SE for fabricated or subcontracted items)</li> <li>• Product Version (Supplied by SE for fabricated or subcontracted items)</li> <li>• Product Serial Number</li> </ul>
MKT-B5R-SYS-0327	Label robustness	Product Markings shall withstand all environments and conditions to which the item will be subjected. Product Markings shall be waterproof and not detach or become unreadable with repeated handling
MKT-B5R-SYS-0328	Module label visibility	Product and Markings shall be clearly visible when the item is installed
<b>Packaging, Handling &amp; Transportation</b>		
MKT-B5R-SYS-0330	Carrying handles	Packaged units with a mass of more than 15 kg and less than 40 kg shall have carrying handles

ID_requirement	Requirement	Value/Content
MKT-B5R-SYS-0331	Lifting points	Packaged units with a mass of more than 40 kg shall have an integral lifting arrangement (e.g. eye-bolts)
MKT-B5R-SYS-0332	Package labelling	<p>The packaging of all line replaceable units shall be labelled, with the following information:</p> <ul style="list-style-type: none"> <li>Item Name (from Config Management System) (fabricated or subcontracted items only)</li> <li>Item Part Number and Version (from Config Management System) (fabricated or subcontracted items only)</li> <li>Item Serial Number where applicable (shall be able to update this for the relevant unit)</li> <li>Unit Supplier Part Number (where applicable)</li> <li>Unit Supplier Identification (where applicable)</li> <li>Packaged weight</li> <li>Container stackability (where applicable)</li> <li>Preservation date (where applicable)</li> <li>Shelf life (where applicable)</li> </ul>
MKT-B5R-SYS-0333	Package markings	<p>Packaged units shall have the following markings securely attached on the outside of the packaging container:</p> <ul style="list-style-type: none"> <li>Mode of transport "careful transportation"</li> <li>"This side up" label</li> <li>"Fork lift here" label, where applicable</li> <li>Centre of gravity marking, where applicable</li> <li>Packaged Item Identification plate, with identification data completed, as specified in the "Package Labelling" requirement</li> <li>Where applicable, tamper proof labels for "wrong way up" and "excessive acceleration"</li> <li>ESD warnings where applicable</li> </ul>
MKT-B5R-SYS-0334	Packaging size considerations	Packaging sizes shall consider standard vehicle transportation as well as entry constraints imposed by doors and corridors
MKT-B5R-SYS-0335	Supply of packaging	Packaging for Spare units shall be provided by the supplier of the units
<b>Safety and security</b>		
MKT-B5R-SYS-0340	Essential Health and Safety	In case of provider from the European Union, the product and all of its subsystems shall conform to the applicable EU Directives. In case of provider outside European Union, the Safety directives and

ID_requirement	Requirement	Value/Content
		their Essential Health and Safety Requirements of its own country shall be applied
MKT-B5R-SYS-0341	Galvanic connection	Equipment mounted on the indexer shall ensure galvanic connection in accordance to IEC62305 LPL III and with resistance of less than 10 milliohm between the equipment chassis and the lightning protection earth interface provided by the Dish Structure
MKT-B5R-SYS-0342	Lightning Protection Zone 2	To protect equipment internal to the band 5b receiver against residual damage from direct and indirect lightning flashes to the structure and external services, the receiver shall establish, and extend on all interfaces, a LPZ 2 in accordance to IEC62305 LPL III, from the LPZ provided by Dish Structure on the power interface and the LPZ it is located in by Dish Structure, as defined in AD0
MKT-B5R-SYS-0343	Locally fail-safe	The components shall be designed to be locally fail-safe and not be dependent on any external inputs for safety
MKT-B5R-SYS-0344	Sharp metal edges	If they cannot practically be eliminated from the design, sharp edges, access openings and corners shall be protected with covers or coatings
MKT-B5R-SYS-0345	Protection against electric shock	Components shall provide protection against electrical shock in accordance with the applicable sections of SANS 60950-1 (for guidance refer to 301-000000-018)
<b>Design Methods</b>		
MKT-B5R-SYS-0350	Safety of machinery risk assessment	A risk assessment shall be conducted for each item of machinery in accordance with BS EN ISO 12100
<b>Facility</b>		
MKT-B5R-SYS-0360	Support Facilities analysis	Requirements for maintenance & storage facilities at all levels of repair shall be identified through a Logistic Support Analysis process using modelling/simulation.
<b>Transportation</b>		
MKT-B5R-SYS-0370	Transportation	All components shall be packaged for Transportation Conditions to prevent incurring any residual damage.  See Section 3 for the Transportation Conditions
<b>Storage</b>		
MKT-B5R-SYS-0380	Storage	All components shall be packaged for Storage Conditions, without incurring any damage, for a period of at least 2 years.

ID_requirement	Requirement	Value/Content
		See Section 3 for the Storage Conditions

Table 9 - Quality Requirements.

## 5. Recommendations

The Table 10 indicates, for some receiver elements, possible solutions that could be adopted by the supplier to reach the system level requirements. These recommendations are not mandatory.

ID_recommendation	Parameter	Value/Content	Note
<b>Low Noise Amplifiers</b>			
MKT-B5R-LNA-0001	Noise temperature	< 3.5 kelvin	
MKT-B5R-LNA-0002	Nominal gain	> 35 dB	Average gain in the RF bandwidth for each LNA
MKT-B5R-LNA-0003	Gain flatness	Within [-1,+2] dB	Allowed interval with respect to the measured average gain for each LNA
MKT-B5R-LNA-0004	Input return loss	< -7 dB	
MKT-B5R-LNA-0005	Output return loss	< -10 dB	
MKT-B5R-LNA-0006	Output Power for 1 dB Compression Point (1dBCP)	> -10 dBm	
MKT-B5R-LNA-0007	Allowable input and output loads	Unconditionally stable	The amplifiers should not oscillate for any combination of passive input and output loads
<b>Cryo-chamber and cold-head</b>			
MKT-B5R-CRY-0001	Operating physical temperature for the LNA	$\cong$ 20 kelvin	The LNAs should operate at this temperature
MKT-B5R-CRY-0002	Operating physical temperature for the PFS	< 77 kelvin	All passive components of the feed system should operate below this temperature
MKT-B5R-CRY-0003	Cooling power delivered	>2 Watt at 20 kelvin >9 Watt at 77 kelvin	The cold-head should ensure this cooling power

ID_recommendation	Parameter	Value/Content	Note
MKT-B5R-CRY-0004	Vacuum level inside the cryo-chamber	[10 <sup>-6</sup> ;10 <sup>-7</sup> ] mbar	The vacuum inside the cryo-chamber should be ensured during the normal operation of the receiver
MKT-B5R-CRY-0005	Moisture collection	1) Use of hydrophobic radome material, where applicable 2) Elimination of traps or crevices susceptible to moisture collection	These design practices should be employed to limit moisture collection in the signal path
Noise Diode			
MKT-B5R-NOD-0001	Operating environment	Inside the cryostat with an operating physical temperature approximately 310 kelvin	
MKT-B5R-NOD-0002	Noise Output ENR	> 40 dB	
MKT-B5R-NOD-0003	Flatness of the noise output	±1.5 dB	
Radio-Frequency Warm Section			
MKT-B5R-RFS-0001	Operating environment	Inside the cryostat with an operating physical temperature approximately 310 kelvin	
MKT-B5R-RFS-0002	Additional gain	To reach the overall gain given in MKT-B5R-SYS-0009	
MKT-B5R-RFS-0003	Slope compensating gain	To reach the flatness given in MKT-B5R-SYS-0009	

Table 10 - Recommendations.