LOFAR

Low Frequency Array

International LOFAR station introductory document

Abstract

This document is intended to be used as input for those organizations who envisage taking part in the LOFAR project and network and has the intention to purchase a LOFAR station. The document forms a source of information on what can be expected and to make a proper judgement if a location is in potential suitable for the installation of a LOFAR station. In order to make a good judgement for a LOFAR site, this document contains a number of site requirements for a minimum performance. To achieve the best results the recommendations should be followed as well to the point that is still practical in a particular situation.

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This document is based on the SRS-019 document Rev 1.6, written by H. Kollen, Y. Koopman, M.J. Bentum, A. Huigen and P. Maat on 19-05-2009. Due to new insights in the International LOFAR Station installation, the SRS-019 document is obsolete now. A new document number has assigned to a major revision of the SRS-019 document including a new document title. This document now is SRS-020.

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1 Introduction

This document is intended to be used as input for those organizations who have the intention to purchase a LOFAR station and who envisage taking part in the LOFAR project and network. It will form a source of information upon which can be decided if a location is in potential suitable to build a LOFAR station. In order to make a good decision, the document contains a number of “must haves” for a minimum performance and to achieve the best results the recommendations should be followed as well to the point that is still practical. It may be very well possible to improve the site and environment at a later stage based on the results of the scientific data analysis.

In this document you will find requirements, recommendations and guidelines for the site location and environment and the preparation of the site, requirements to the infrastructure as well as information about the station installation.

This document does not include the placement and installation of equipment, resources planning etc. required for a LOFAR station. These items will be described in a separate document.
Furthermore, this document will not elaborate on functional, performance and operational aspects of a LOFAR station because these are documented elsewhere and will be agreed separately.

It is highly recommended that the customer sends a representative to LOFAR/ASTRON in The Netherlands in order to become acquainted with the LOFAR equipment and to get practical information regarding installation and maintenance of a LOFAR station.

1.1 Scope and limitations

The purpose of this document is to support the search for potential LOFAR site locations and to advise on the preparation work in case the search proved to be positive. Specific issues, in particular the layout of the antenna fields and the RFI conditions of the selected LOFAR site locations may differ from the specifications and requirements mentioned in this document and should be discussed with LOFAR specialists. These specific issues will be covered in separate documents and drawings.

A best effort has been made to make this document complete and generic as possible however, some issues might not have been covered or incomplete.
This specification does not cover aspects like:

- Cost issues
- Installation
- Maintenance
- Operations and operations fee
- Agreements with CEP regarding use of storage, processing time allocation etc
- Publications
- Data ownership
- Disposal phase
- Contractual issues

1.2 Definition of LOFAR

The LOFAR Phase 1 Baseline consists geographically of a Compact Core area in the North-East of the Netherlands and Remote Stations in the area around the core; with a maximum baseline of ~100 km. Stations are oriented such that future extensions of international stations can contribute to the spiral layout of LOFAR and add significantly spatial sampling for the astronomy applications. Longer baselines are already realized by the European extensions of stations in Onsala, Effelsberg, Unterweilenbach, Tautenburg, Potsdam, Juelich, Nançay and Chilbolton and more stations are expected.

The ICT infrastructure that LOFAR holds, has great potential for non-radio astronomers, enabling them to make strides in monitoring at an accelerated pace. In the geosciences field, it should be possible, for example, to extend the understanding of natural and induced seismicity, subsidence, and water management. The Technical University of Delft, the Royal Dutch Meteorological Institute (KNMI) and TNO-NITG are participating in the application of LOFAR in the geosciences.

The advanced network of fiber optics will transport also geo-scientific measurement data. The following are examples of the involvement of the geo-scientific participants in the consortium:

- Seismic applications
- Infra-sound applications
- GPS/INSAR applications on subsidence
- Groundwater monitoring
- Pressure and temperature monitoring

The Core area, with 2 km in diameter, is covering a total of 24 stations, each station will consist of Low Band and High Band Antennas.

Outside the core area, installed in a spiral shape layout with a diameter of approximately 100 km, a total of 14 Remote Stations are equipped with High Band- and Low Band antennas.
A number of selected stations are equipped with additional sensors for geo-scientific application.

Remote stations are connected by 10 GbE technology to the Central Processing systems (CEP). The sensor data will be dominated by the astronomical antennas (about 2.7 Gb/s, being the equivalent of a single dual-polarized beam over 48MHz, so 1x48MHz or 8x6MHz etc). For the astronomy application, full Tied Array beam forming is supported. Transient detection is also supported. Buffering of the full sampled bandwidth and limited triggering will be available at station level.

For international connections the data from the international sites will be transported to CEP. The total data-rate is equivalent to the stations in the Netherlands which is about 2.7 Gb/s of sampled data plus some overhead for metadata and monitoring and control. This requires a 3 Gb/s fiber connection, to be realized by either three 1 Gb/s connections or one 10 Gb/s connection.

For international sites it may not be obvious to combine other applications with the astronomical purposes. If there are intentions to accommodate other applications on or near the astronomical site there are a few important interface criteria that will be mentioned in section 2.5 of this document.

1.3 Background design information

In this chapter some aspects that are considered important for the Astronomical Applications are discussed below:

- Low Band Antenna element, optimized for the 30-80 MHz range, with a sharp cut-off filter above 80MHz. The suppression below 30MHz will be matched to the environment. The Low Band antenna elements can be used down to a 30 degrees scan angle w.r.t. the ground.
- High Band antenna can be used between 120-270 MHz.
- The FM band is suppressed in the antenna amplifier for both antennas to minimize intermodulation products from local broadcast FM transmitters.
- Broad-band integrated receiver and digital processing system. The receiver uses direct conversion of a 80/100 MHz band. Each receiver is connected to a Low Band antenna and to a High Band Array tile; only one of these can be selected at a time. (Note that there is also a third input available on the receiver units: The Low Band Low Antenna. However, this will not be part of the baseline.) The 100 MHz signal will be buffered for ~1 sec for Cosmic Ray detection and Transient Processing. In the first digital processing step 156/196kHz sub-bands are formed. Only a subset of these bands is further processed. The maximum total bandwidth selected for further processing will be 48 MHz. Each Remote Station delivers a single dual polarized beam at 48 MHz, or 8 dual polarization beams at 6 MHz. The resulting output data rate is about 3 Gb/s. The secondary filtering stage (to 1kHz channels) is done in the Central Processing system.

1.4 Glossary

This section provides the meaning of the abbreviations used in this document.
A more elaborated description of definitions and terms is provided in "LOFAR Terms, definitions and abbreviations", LOFAR-ASTRON-RPT-002 (RD.7)

ADD	Architectural Design Document
BCK	Backplane
CCU	Central Control Unit
CEP	CEntral Processing
COTS	Commercial Off The Shelf
EMC	Electro Magnetic Compatibility
EoR	Epoch of Re-ionisation
HBA	High Band Antenna
HBA-FE	High Band Antenna Front-End
HW	Hardware
ILT	International LOFAR Telescope
JTB	JTAG Test Board
JTAG	Joint Test Action Group
LBA	Low Band Antenna
LCU	Local Control Unit
LNA	Low Noise Amplifier
LOFAR	Low Frequency Array
MAC	Monitoring And Control
MoM	Minutes of Meeting
NAA	Non-Astronomical Applications
PSU	Power Supply
RCU	Receiver Control Unit
RFI	Radio Frequency Interference
RSP	Remote Station Processing Board
SPU	Station Power Unit
SW	Software
TBB	Transient Buffer Board
TBC	To Be Confirmed
TBD	To Be Defined, Determined
TBW	To Be Written
UHECR	Ultra High Energy Cosmic Rays
WAN	Wide Area Network

1.5 Applicable and reference documents

1.5.1 Applicable documents

The LOFAR applications design will comply with the list of applicable documents, to the extent stated herein. In case of conflict, this specification shall have precedence.

No.	Document Number	Issue/rev	Title
AD.1	EN55022-B		EMC standards
AD.2	IEC 61000-4-3		Radiated immunity
AD.3	IEC 61000-4-6		Conductive immunity
AD.4	IEC 62305		Protection against lightning

1.5.2 Reference documents

The following list of reference documents provides a description of the design of LOFAR, the central system and its stations seen from the astronomical point of view. They can be used as a source of background information for the interpretation of the requirements in this document and may be helpful for the design of applications other than astronomical.

No.	Document Number	Issue/rev	Title
RD.1.	LOFAR-ASTRON-MEM-145	2.0	LOFAR phase I baseline
RD.2.	LOFAR-ASTRON-SRS-001	4.2	System Requirement Specification
RD.3.	LOFAR-ASTRON-SRS-012	1.0	Station Requirement Specification
RD.4.	LOFAR-ASTRON-ADD-006	2.0	System ADD
RD.5.	LOFAR-ASTRON-ADD-013	1.0	Station ADD
RD.6.	LOFAR-ASTRON-MEM-142	Xx	LOFAR remote station baseline
RD.7.	LOFAR-ASTRON-RPT-002	2.0	LOFAR abbreviation and glossary
RD.8.	TBW		LBA mounting procedure
RD.9.	TBW		HBA mounting procedure
RD.10	LOFAR-ASTRON-ADD-009	2.0	LBA architectural design document

2 LOFAR Station description and specification

The configuration of an international LOFAR station consists of:

- 2 astronomical sensor fields with a minimum size of 75 x 75 meters each.
- 1 modified sea container that includes a RF shielded section for the station electronics

Note: If desired the antenna fields might be extended with an optional sensor field including equipment cabinet that can be used for non-astronomical purposes (see section 2.5).

The sensor fields contain the following sensor types:

- One LBA astronomical sensor field comprising up to 96 LBA antennas
- One HBA astronomical sensor field comprising up to 96 tiles containing 16 HBA antenna elements each.
- One passive (dummy) HBA tile including antenna elements without electronics.

The astronomical application will be considered in this document. A general description of the station can be found in RD.1 “LOFAR Remote Station Baseline”, document LOFAR-ASTRON-MEM-142. The reference documents RD.4 and RD.5 provide a description of the LOFAR respectively station design. Summarizing, the following components will be needed for a station:

Item	Quantity
LBAs	96
HBA tiles	96
HBA element per tile	16
HBA passive tile	1
Modified sea container with 4 x 19” racks containing all station electronics (detailed in chapter 0)	1
Coax cables to LBA field (2 per each element)	192
Coax cables to HBA field (2 per each active tile)	192

2.1 Physical parameters of a station

The physical location and orientation of the container shall be relative to the antennas as indicated in Figure 2-1 or Figure 2-2 and is related to the coax cable lengths. However, these are general pictures. The LBA, HBA and Non-Astronomical field positions may depend on the site dimensions that are locally available and other aspects of the terrain and surroundings. Each site is unique so that the station- layout and various options shall be determined specifically and mutually agreed between the LOFAR management and the customer.

Figure 2-3 shows a more specific POLFAR layout specification. The position and orientation of the container with station electronics can be selected in such a way that it complies best with the site layout and maximum length of the supplied coax cables. RFI properties of the container does not play a role in the layout considerations since the provided container will be RF shielded (> 80 dB over a frequency range of 100 kHz to 10 GHz).
The optional NAA cabinet shielding should have an attenuation of > 40 dB over a range from 100 kHz – 300 MHz.

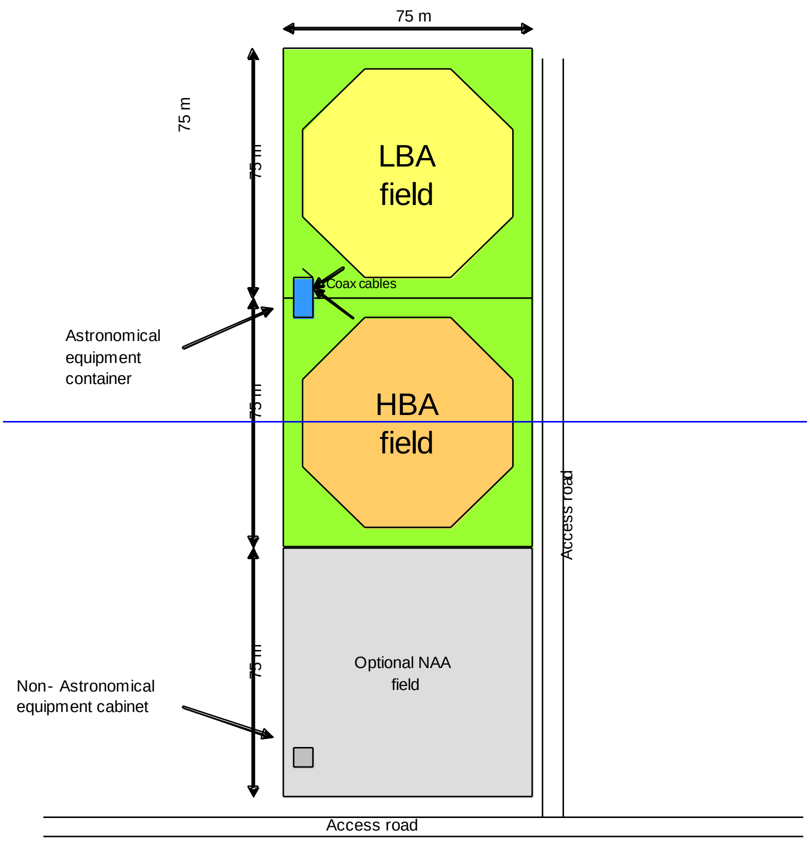


Figure 2-1 Remote station layout example 1

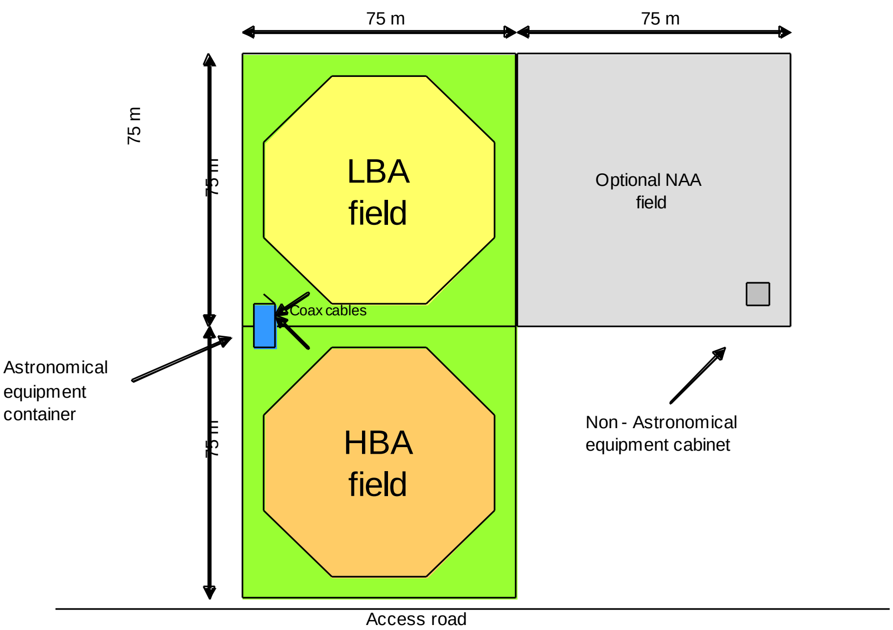


Figure 2-2 Remote station layout example 2

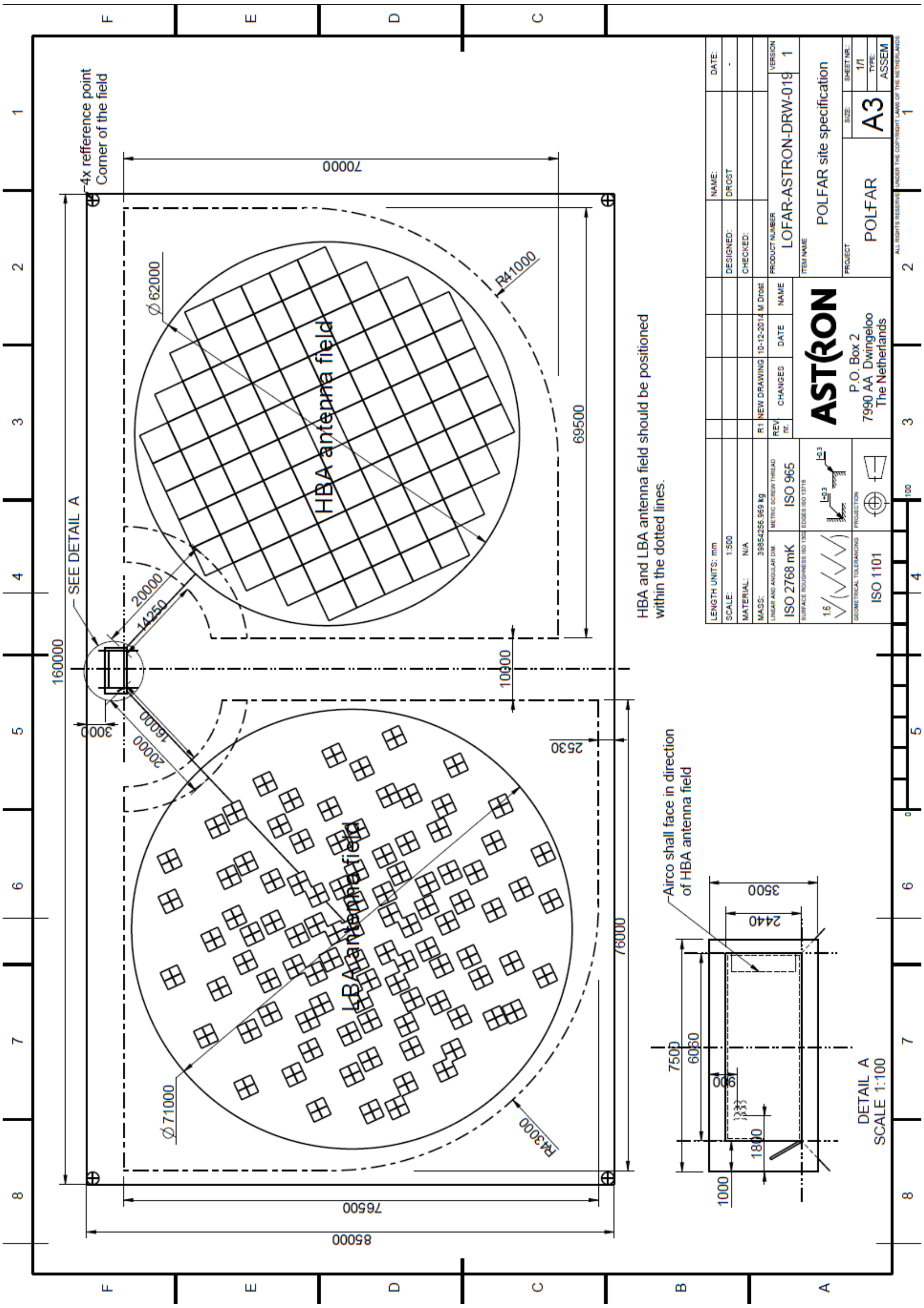


Figure 2-3 POLFAR station layout specification

Station electronics

The station electronics will be housed in a RF shielded compartment that is part of a modified sea container. In the RF shielded compartment 4 equipment racks (19") are placed that hold the station electronics. The container is equipped with air-conditioning in order to keep the temperature of the electronics within the operational range.
The container has the following specifications:

- RF attenuation	> 80 dB @ 100 kHz to 10 GHz
- Size (width x depth x height)	2.5 x 6 x 2.9 m
- Weight:	approx. 4500 kg
- Colour of container:	RAL 7039
- Operation temperature range:	- 20 ºC to +40 ºC

The container will require a level support on each corner and will be resting on a foundation in the form of a cast concrete plate of 3.5 x 7.5 meters. The concrete plate needs specific feedthrough holes and guiding provisions for power, data and the coax cables coming from the antennas, see Figure 2-4 and annex 5.2.

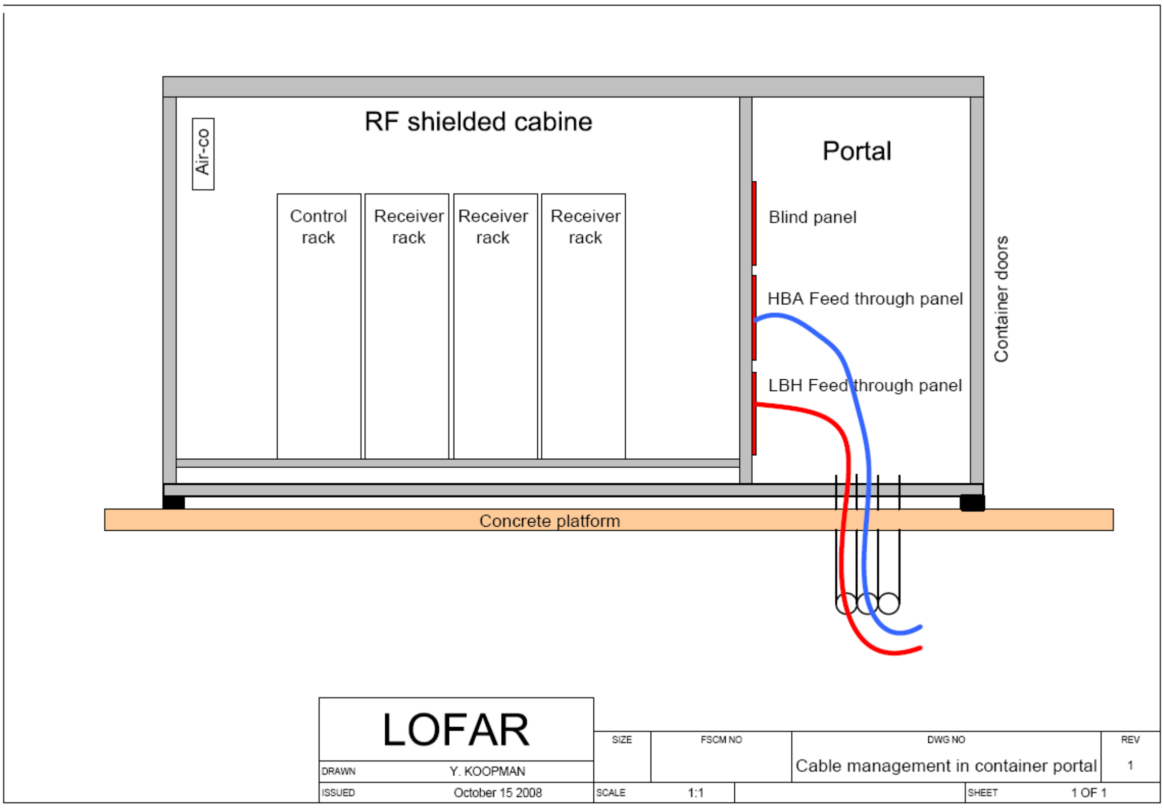


Figure 2-4, LOFAR international equipment container

Station electronics compartment in container
The LOFAR station electronics is assembled in four interconnected 19" racks, Figure 2-5. The first three racks contain receiver subracks and the other rack holds the control equipment, time reference equipment, switches and the power supply.

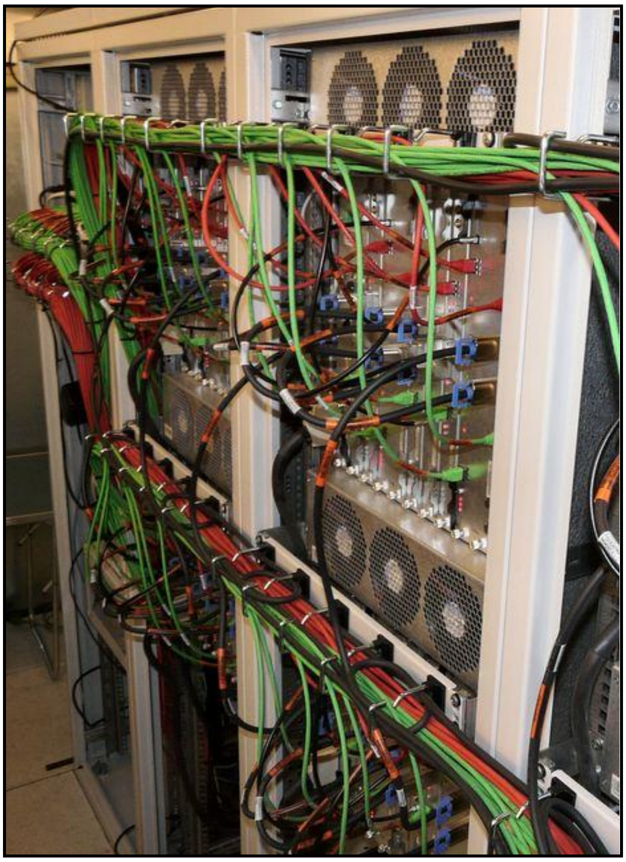


Figure 2-5, front and back view of the 19" equipment racks

Receiver racks (number 0, 1 and 2) layout:
Two (2) receiver subracks per rack, in total six (6) subracks with each:
- 32 RCU (Receiver Unit) boards
- 4 RSP (Remote Station Processing) boards
- 1 backplane
- 1 SPU (Sub-rack Power Unit)
- 2 TBB (Transient Buffer) boards
- 1 TDS (Time Distribution System) board
- 1 JTB (JTAG Test Board)

Control, interface and power equipment rack (number 3) layout:
- mains power distribution panel
- line relays panel (remote switch +48V, LCU and heater)
- Power unit (+48V DC)
- LCU (Local Control Unit)
- Two Ethernet switches, including fibre modules
- Glass fibre termination/splice unit
- GPS receiver

- Rubidium clock
- 2 SyncOptics units

Two antenna cable feed through panels with each 2 times 96 inputs (mounted to the RF compartment wall) Additional panel for future inputs (mounted to the RF compartment wall) see Figure 2.1-5.

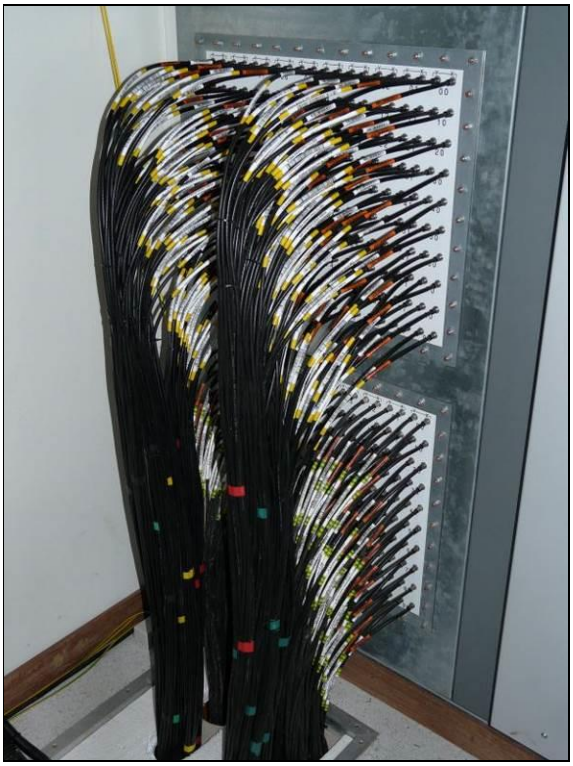



Figure 2-6, Coax feed through panel

2.1.1 Electrical parameters

This chapter provides an overview of some important electrical parameters.

Power specification

Maximum power consumption 3-phase of total station, equal load per phase: 15 kW
(including 1200 W for air-conditioning)

Maximum power dissipation in container (excluding air-conditioning): 8.8 kW
Maximum power dissipation/consumption antennas HBA (worse case): 6.5 kW

Data interface specification

Station maximum data rate 1x 10 Gb/s

Connector types

LBA antenna connector: F-connector
HBA antenna connector: F-connector
Data cable connector (as delivered) Glass fibre ST-connector

Antenna Cabling:
Coax-9 cable, F-connector type assembly, delivered in various standardized lengths ranging from approx. 50 up to 130 m,

2.1.2 LBA and HBA field specifications

This section provides general and more specific requirements for the LBA and HBA fields of international LOFAR stations. The justification and some background information for these field specifications is provided in chapter 2.4.

General specifications and recommendations for LBA and HBA fields:

- Antennas should be placed on a plane that does not need to be parallel to the LOFAR core fields, i.e. the plane can have an inclination. However, from a practical point of view the inclination should not exceed a point where the antenna installation and anchoring becoming impossible or insufficient.
- A few degrees inclination of the field, preferably towards a ditch is recommended for drainage purposes, especially for the HBA field.
- The HBA & LBA fields do not need to be on the same plane nor do they need to be parallel to each other.
- Antennas should be set up normal to the plane.
- No outlier dipoles are required.
- Random single footprint for the LBA station layout.
- HBA tile layout most likely regular; confirmation tests still need to performed.
- Antennas will be rotated by a specific angle including a correction for longitude and latitude which varies from station to station. LOFAR will provide the exact antenna positions for the various international LOFAR stations.
- LBA dipoles and HBA dipoles should be parallel oriented within a station to +/-2° accuracy (maximum deviation).
- LBA and HBA dipoles should be as parallel as possible across all LOFAR stations (including ILT stations).

LBA field specific requirements:

- Nominal field size:	approximately 75 x 75 m. square.
- Amount of LBA antennas:	96
- Ground plane size:	3 x 3 m.
- Flatness requirement of the field	± 6 cm (rms deviations, the systematic error much smaller)
- Antenna orientation	≤ 1 degree
- Deviation in antenna orientation	≤ 1 degree
- Deviation of angle between the 2 poles of the v	≤ 5 degrees
- Maximum length LBA cable	115 m.
- Nominal cable depth in ground	60 cm

HBA field specific requirements:

- Nominal field size:	approximately 75 x 75 m. square.
- Amount of HBA tiles:	96 + 1 dummy tile
- HBA tile size	5 x 5 m
- Intra-tile distance	15 cm
- Flatness requirement of the field	± 3 cm (rms deviations, the systematic error much smaller)
- Tile antenna orientation	≤ 1 degree
- Deviation of antenna position from specified coordinate	≤ 1 degree
- Maximum length HBA-tile cable	130 m
- Nominal cable depth in ground	60 cm

2.2 Preferred site location and environment

The astronomical performance of a station is depending on the location and its environment (currently and in the future). A station site is preferably located in a fairly isolated place which is 2 km remote from nearby overhead power lines and relatively far from any highways, roads with heavy traffic, railroads or tramways. It should also be located as far as possible from villages, towns, industrial- or other urbanised areas.
Wind turbines for generating electrical power may also have a big impact on the station performances. The effect mainly depends on the distance from the wind turbine(s) to the LOFAR station, the size- and the number of wind turbines. A >4 Km range from the wind turbines is found to be a practical distance as experienced with the Dutch LOFAR stations.
Strong RFI signals inside and outside the LOFAR frequency band will not only block the astronomical observation but can also cause severe intermodulation in de electronic system. A RFI measurement at the exact location is highly recommended.

The station is best located in a rural area or forested areas or at the fringe of a nature reserve. The latter will require good communication with environmentalists and nature organizations. In rural or forested areas one should take into account that the land up to 100 m around the site itself should be clear of any high trees or structures. At the south border of the site, this free area should be about 200 m. Nearby trees or structures higher than 20 m will limit the maximum antenna scan angle (based on a desired minimum elevation angle of 10 degrees).

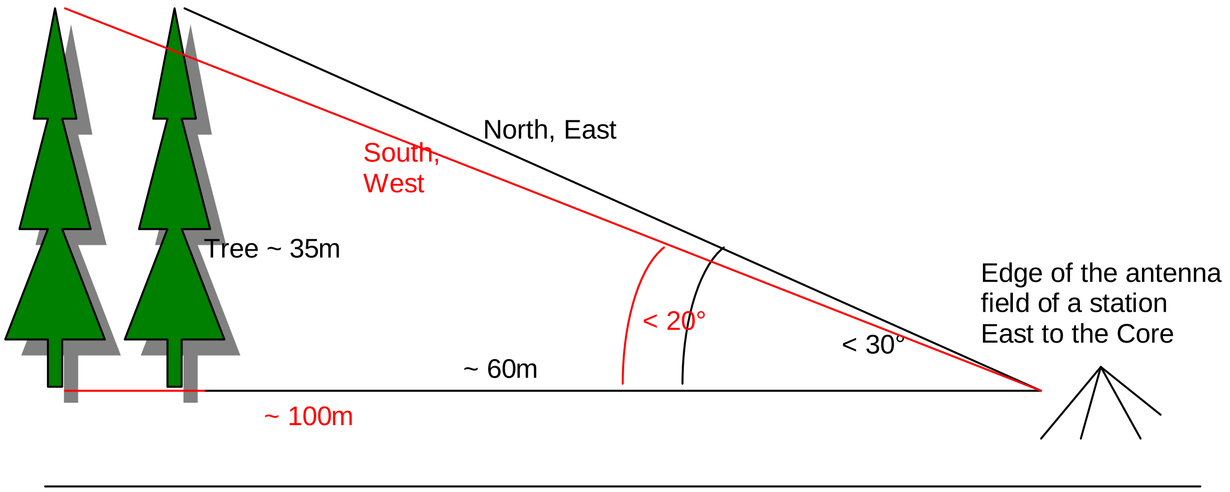


Figure 2-7 antenna scan angle

In conclusion, the trees or a dense forest might block the field of view of a LOFAR station for low antenna beam elevations. The accessibility of low elevations is crucial for Jupiter and solar observations in the winter as well as for observations of sources with overlap of optical telescopes in the Southern Hemisphere.
From these scientific considerations, the minimal requirement for the field of view of a very remote LOFAR station is a scan angle down to 30° elevations in all directions for all antennas in a station. If possible, a clear view down to 20° elevations in all directions especially towards South for all antennas in a station is preferred. Even access to lower elevations of about 5°-10° especially towards South might be desired scientifically but are not necessary. Furthermore, one could take into account that stations east from the LOFAR core might want to be able to observe further down into the western direction and vice versa. The same applies for Northern and Southern stations. The little geometric exercise implied (for a station East of the LOFAR core) is shown in Figure 2-7. Note that the distances depend on the height of the trees.

Please note that it will be necessary to conceal the cables in trenches with a nominal depth of 60 cm. It is recommended that the land will be declared free of any potential archaeological findings or other future digging for (industrial) pipes or cables. The depth can be adjusted to the local situation of the soil. Concealing the cables will prevent damage by e.g. rodents or maintenance activities such as mowing etc.

2.3 The site properties

The site should be accessible by at least a macadam- or sandy road in order to get the equipment on the fields. The gross dimensions of the site to be acquired should be in the order of 3 – 4 ha (200 x 200 mtr), but different sizes up to a width of 100 meter are possible as well. The site should be sufficiently large to fit a LBA and HBA field (see Figure 2-1 and Figure 2-2) including some space for a service driveway and ditches or other natural barriers if required. If it is preferred to locate the site on land owned already by an institute, the minimum LBA and HBA field dimensions (preferably 75 x 75 m per field) have to be respected. The surface must be equalized as much as possible (see section 2.1) and it should be drained well enough to prevent collection of water on the LBA ground planes during prolonged periods of time (e.g. < 30 minutes). A small inclination of the field will, in most situations improve the drainage. Water on the ground planes will change the performance of the LBA.

It is obvious that metallic or electric fences to separate the site from the surrounding should not be used because these will have an impact on the performance of the station. However, by using natural barriers

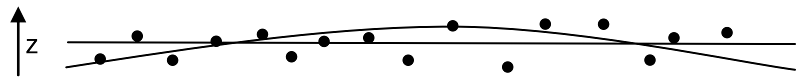
(ditches, swamps, and hedges) entrance can be made difficult regarding inadvertent access of public and animals. Stations will be delivered by ASTRON/LOFAR without any fences.
Rodents are a threat for any unprotected cabling above ground.

A rocky soil is a thread for buried coax cables in the ground (trenches), sharp rocks may damage the cables and either protection of the cables or local removal of the rocks is highly recommended.

2.4 Station lay-out specification justification and background information

An ILT station field
In the course of the re-scope discussions, it was recommended that an nternational LOFAR station also called “ILT station” should consist of 96 LBAs and 96 HBA tiles. All LBAs or all HBA tiles should be operable at the same time. This was recommended to increase the sensitivity on the long baselines, which can be up to a 1000km.

The station area should be planar for the LBA field and the HBA field. The area might have an inclination but the antenna fields should be planar to an accuracy of about +/- 6 cm for LBA and +/-3 cm for HBA. These numbers are rms values for random deviation. However, the systematic error should be much smaller (see figure below). The LBA and the HBA field do not need to be in the same plane nor do the planes need to be parallel to each other. However, the exact locations of the antennas must be known.



Both situations fulfil the +/- rms requirements, but the systematic error is very different

The required planarity is justified by the following arguments. The Ruze formula gives an initial requirement of an accuracy of $\lambda/25$, i.e. +/-15cm for LBA (at 3.75m) and +/- 5cm for the HBA (at 1.25m).

Because of height differences of antennas the beam pattern will differ from station to station which produces different beam patterns for the various stations. This will have the biggest effect on the far side lobes where these small variations can have a large impact. These side lobes introduce artefacts.

In order to achieve beam patterns that are as similar as possible, the station area should be as planar as possible. Therefore, as a minimum requirement for LOFAR, an accuracy of +/-6 cm for the LBA field and +/-3cm for the HBA field is requested for an ILT station (see chapter 2.1.2). The antennas should be erected upright (perpendicular) to the plane.

ILT Antenna footprints

LBA field layout
The 96 LBAs will be placed in a random fashion following the layout in **Fout! Verwijzingsbron niet evonden.**. A single random configuration has been chosen already to suppress side lobes. It is possible to adapt the position of a couple of the outer antennas so that the LBA station field fits within the constraints given by the land available.

HBA field layout
An HBA tile is 5m by 5m wide. They will be most likely placed in a regular grid. The intra-tile distance is 15 cm. The final HBA tile station layout needs to be confirmed by tests that are ongoing.

Remark:
Due to a different LBA layout for the Dutch LOFAR stations, additional outlier dipoles are used for calibration purposes for the cosmic-ray application. In this mode an inner circle of 48 LBAs are in use and the outliner dipoles that are part of the outer LBA circle providing a larger baseline for calibration.
However, this mode is not applicable for ILT stations since these stations can benefit from the additional back-end channels. An outliner dipoles configuration is therefore not foreseen in the ILT layout.

Antenna field rotation
The far side lobes of the station beam are a concern for the LOFAR calibration. One strategy to average them out is to rotate the station footprint from station to station. The rotation angles should range over 360 degree. As the layout of the ILT stations is different from the core and remote stations only about 15-17 possible rotation angles are needed. As the beam patterns are symmetric, the rotation of the station footprint should not be symmetric. Symmetric rotation will not have the effect of cancelling side-lobes. The suggestions is thus to define about 23 rotation angles to choose from, i.e. steps of 15.65˚. In addition, one should correct for latitude and longitude differences. A spread over 360˚ should be achieved in the areas north-east from Exloo, south and north-west from Exloo. The rotation angle is defined by a rotation north over east. As Effelsberg is the first complete LBA ILT station, it is suggested to use its layout and antenna/dipole positions as a reference.

Determination of the rotation angle can lead to misunderstanding. The LOFAR project scientist will therefore provide the rotation angle for the ILT stations taking the above-mentioned consideration into account.

Parallel dipoles
For the Dutch LOFAR core and remote stations it has been advised to place all dipoles parallel to each other. This is in the first place important to support the calibration and secondly important for the tied array beam forming. At the distances of ILT stations it is due to the earths curvature and, in some case the station inclination no longer possible to have the parallel dipoles.

Within a station it is still recommended to install the dipoles as much as possible parallel to each other. This will simplify the (station) calibration.

2.5 Non-Astronomical applications (optional)

The optional third sensor field (Figure 2-1) can contain e.g. sensors like geophones, hydrophones and infrasound sensors (such like for the Dutch LOFAR sites)
In case that it is envisaged that the station should accommodate Non-Astronomical Applications as well, the following issues shall be accounted for:

- Any intention to accommodate another application shall be agreed with ASTRON/LOFAR
- Physical location: See section 2.1
- Power consumption/dissipation: The NAA power consumption has to be added to the site total power consumption, it is not foreseen in the astronomical power budget
- Data connection: To be inserted on the LOFAR network via the splice box/optical modules
- Data rate: To be agreed with LOFAR
- EMC requirements for any equipment installed: The maximum emission level for electronic equipment on a LOFAR site is 15 dBµV/m at 100 meters distance from the equipment [AD.6]. This excludes any additional requirements of e.g. a radio telescope that is located nearby.
- The Non-astronomical cabinet/electronics should be located as far as possible from the LBA/HBA fields, depending on the type of equipment and the expected level of RFI disturbance.
- An optional NAA cabinet must have an electromagnetic attenuation > 40 dB from 100 kHz – 300 MHz.
- A non-astronomical application partner is given the opportunity to transfer the data from its equipment at a specific ILT site via the ILT data link of that site. In case the partner makes use of this option, a single 1000BASE-T port will be available per partner in the partner cabinet. This port will provide a connection to a 1000BASE-T port on the lightpath switch at the LOFAR central processor site at Groningen. Alternative connections will not be provided. For the non-astronomical application link the following should be taken into account:
  - The non-astronomical application data will be transferred via a single VLAN per partner. ASTRON/LOFAR will determine its VLAN ID.
  - The connection will provide a bandwidth with a maximum of 100Mb/s per direction per partner.
  - The availability of the partner links cannot be guaranteed.
  - The partner has the responsibility to connect his equipment to the data transfer system in such a way that the LOFAR data link will not be endangered in any way. In case LOFAR/ASTRON notices any problems, that originate from the partner's data link, it will be disconnected. In order to prevent such a situation the following preventive measures are strongly recommended to be taken by the partner:
  - Installation of an adequate firewall and intrusion detection system between the VLAN or its systems at the ILT station site and the Internet and /or other, non-LOFAR networks
  - Avoid traffic and link configuration problems by strict implementation of the guidelines provided by ASTRON/LOFAR
  - In case a partner detects an intrusion in one of his ILT systems, this should be directly (within 1 hour) reported to ASTRON / LOFAR.
  - Using types of traffic/standards that are compatible with the LOFAR network in consultation with ASTRON/LOFAR
  - The partner equipment will be placed in a separate cabinet. In this cabinet a Foundry LS648 (partner) switch is placed that will provide the 1000BASE-T connections to the partners. This partner switch will be connected to a switch in the ILT cabinet. Both switches are connected via a 1000BASE-LX optical connection. The fibre-optic cable and its terminations that are needed for this connection must be designed, deployed and maintained in such a way that the mentioned 1000BASE-LX connection will function according to its specification. This cable must be terminated in both cabinets on patch panels with SC/PC patch positions.
  - Any maintenance to the mentioned fibre-optic cable must be reported at least 1 week in advance. In case the announced maintenance does not concur with LOFAR scheduling the partner and LOFAR/ASTRON should agree a more suitable timeframe.

3 LOFAR Station site evaluation

The following chapters provide a set of basic issues that should be completed prior to setting up a LOFAR site that will provide a performance that is compatible with the other stations in the LOFAR instrument. Violation of one of these items does not mean that the station will not work at all, but it may have an impact on the performances. The intention is to realize as many of these items as possible in order to realize an adequate station performance.

Note that the sections below contain similar information as in section 2, but presented in the concise form of a detailed checklist.

3.1 Site evaluation checklist

This chapter provides the basic desired properties of the physical location and the site that will be favored for the installation of an ILT station. It may be impossible to meet all items initially, but after discussion with LOFAR specialists and after evaluation of measurement data, improvements could be made in some areas, such as cutting a tree or forest line or changing a fence. No single item below, if not met, would make it impossible to establish a site at the preferred location, but will more or less influences the performance. An optimum performance will be achieved in case all statements below can be checked positively. If none of them are met the situation needs to be improved. Consultation of LOFAR specialists may be required to indicate which points need the most attention.

Site evaluation check list:

Nr.	Description of statement	Check
1	It is possible to fit one HBA field and one LBA field of each 75 x 75 m in accordance with the possible configurations as indicated in Figure 2-1 and Figure 2-2 including a service driveway on the selected site.	
2	Adequate draining of rain water on the site is available. Puddles due to heavy rainfall should be drained after 30 minutes	
3	The site shall be accessible via at least a macadam or sandy road	
4	The station is not located within 2 km of any overhead high voltage power lines (10 kV and higher)	
5	The station is not located within 6 km of any radio or TV transmission station	
6	The station is not located within 2 km of any railroad or tramway.	
7	The station is not located within 4 km of any windmills in specific wind-turbines for electrical power.	
8	The station is not located within 500 m of any main road or roads with heavy traffic	
9	The station is not located within 500 m of any urban (industrial) development	
10	The station is not located within 100 m of forest, single high trees or structures higher than 10 m	
11	The land adjacent to the station towards the south direction is cleared from any high trees or structures higher than 20 m over a distance of 200 m	
12	The site is not enclosed by metallic or electrified fences	

3.2 EMI/RFI environment

All electronic equipment at a LOFAR station, except the sensor electronics, is installed inside a shielded outdoor cabinet. The level of shielding is sufficient for the LBA and HBA functionality and operations. The maximum emission level from the equipment inside a standard LOFAR cabinet is 15 dBµV/m at 100 meters distance from the cabinet [AD.6]. The emission level is far below the CE requirements stated in [AD.1]. The Dutch LOFAR stations are using cabinets providing a 40 dB shielding. However, ILT stations are often located on sites owned by scientific institutions where more sensitive sensors such as large radio telescopes are present. Therefore an ILT station will be provided with a (certified) container including a shielding of >80 dB over a range from 100 KHz to 10 GHz.

A LOFAR station is a fixed installation and needs to comply with the new EMC directive 2004/108/EC from 20 July 2007 onwards. This means that no conformity assessment is necessary. Also CE marking is not required. The new EMC directive demands however adequate documentation and a point of contact who will be responsible for the station. ASTRON/LOFAR will provide the required documentation as part of the final delivery and acceptance of the station. The station owner must to appoint and provide the name of the responsible person which will be included in the documentation.

Nr.	Description of statement	Check
1	Are the emission and immunity requirements for electronic equipment installed on or near the LOFAR site compatible with the mentioned E-field strength level?	

Note: In case an optional cabinet for other applications than astronomic will be placed, it should at least respect the points regarding RFI mentioned in 2.5.

4 Customer support

Once the site has been selected by the customer and agreed with the LOFAR project manager, a number of issues will have to be taken care of by the customer in order to prepare the installation of the ILT station. These points are discussed in the following sections. In annex 5.5 an example illustrates the planning and progress of the construction of a Dutch LOFAR station.
The ILT station installation will be finalized by the delivery of a technical acceptance test.

4.1 Overview of support tasks

This chapter provides an overview of various tasks to be carried out for the ILT site preparation and installation. It also serves as an indication of the boundary responsibilities of parties involved, but has not the intention to specify all binding conditions. The final contract will eventually define these responsibilities and will be leading.

The baseline will be that the customer is responsible for successfully and adequately carrying out the various tasks. ASTRON/LOFAR can offer recommendations and serving as an advisory party for the following:

- Suitable site acquisition (remarks: area, surroundings, RFI etc.)
- Site preparation (ground work)
- Geodesy activities
- Placement of a concrete container foundation including cable feedthrough pipes
- Mechanically and electrically installation of the container including electrical grounding (AD.4)
- HBA tile and LBA antenna placement including routing of coax cabling (in trenches)
- 3 phase mains cable up to connection on the main switchbox in the container
- data cable (glass fibre) including provision of a splice box and optical modules up to connection to the network switch equipment (switches are delivered by ASTRON/LOFAR)
- Providing support during ASTRON/LOFAR integration and test work

The following points but are the responsibility of ASTRON/LOFAR:

- Providing the specific ILT design and drawings
- Delivery LOFAR hardware, see Table 4.7-2
- Delivery of container including equipment, see Table 4.7-2
- Integration of rack equipment in container
- Testing, concluding with acceptance
- Providing the Data Delivery Package (contains all relevant information regarding the delivered station)

4.2 Geodesy, determination of exact antenna positions

NA

4.3 Field preparation and equipment placing

Field preparation is an important issue and the customer is requested to carry out this work, gaining valuable experience regarding the preparation and installation of a LOFAR station.
The table below contains detailed steps that have to be taken in order to prepare the installation of:

- HBA and LBA field preparation
- Container foundationand installation
- Antenna cable routing
- HBA and LBA placement, location and accuracy

1	The site, especially the HBA and LBA fields should be prepared by the customer in accordance with the specifications in section 2.1.2 and by considering the additional points mentioned in chapter 2.4.
2	Coax cables have to be buried for protection and better temperature stability. A nominal depth of 60 cm is recommended either in the natural soil or in an artificial layer of sand on e.g. a rocky soil. If the soil is an artificial layer it should be stabilized prior to the antenna installation.
3	Coax cables have to be handled carefully in order to allow all antennas to operate nominally: - personnel should not walk or stand on the (bare) cables (make trenches not too wide) - cable overlength should be buried in large loops without coiling of the cable - sharp bending should be avoided (bending radius not less than 10 cm) - connectors should be protected always against dirt and water until connection - protect cables against sharp rocks if buried in rocky soil
4	The LBA and HBA field position and orientation should be determined and marked as guided by the site specific drawings, taking into account the specific form and dimensions of the site at hand, see section 2. The general site reference drawing in annex 5.1 gives an example layout.
5	The position and orientation of the container should be determined and marked as specified in the station design drawings. Generally, the cable entry openings should be directed towards the antenna fields (yielding the shortest cable length). Annex 5.1 gives an example of an antenna layout.
6	The 96 LBA positions and orientation must be determined and marked by means of small poles (pickets) with an accuracy of 1 degree from the specified coordinates in the station design. The LBA orientation should be determined with an accuracy of better than 1 degree.
7	The position and orientation of the 96 HBA tiles should be determined and marked on the HBA field by means of small poles (pickets) with an accuracy of 1 degree from the specified coordinates in the station design. The HBA tile orientation must have an accuracy of better than 1 degree.
8	The LBAs must be installed accordance to the procedure provided as a separate document (see RD.8). Note: A plastic foil of 3 x 3 m is placed under the metallic ground plane of the LBA in order to prevent plant growth that may influence antenna characteristics. If the properties of the soil are already (or chosen) such that plant growth is inhibited by nature this foil maybe omitted.
9	The HBA tiles must be installed accordance to the procedure provided as a separate document (see RD.9)
10	The concrete foundation has to be cast in accordance with the drawing in annex 5.2.
11	The concrete container foundation has to be provided with pipes to guide antenna cables and other cabling into the container in accordance with the drawing in annex 5.2.
12	The container has to be placed on the concrete foundation in accordance with the drawing in annex 5.2
13	The container needs to be adequately grounded according to latest norm (AD.4).
14	After installation of all LBAs, the exact antenna positions (of the LNA head) should be measured with an accuracy of $\pm$ 1 cm, which will form the new reference set of antenna coordinates for astronomical observations
15	After installation of all HBA tiles the exact tile positions should be measured with an accuracy of $\pm$ 1 cm which will form the new reference set of antenna coordinates for astronomical observations

4.4 Infrastructure

This chapter describes the ILT infrastructure that is needed to operate the station i.e. the power connection and the data connection. The data connection forms the umbilical with the LOFAR system and will be used to command and monitor the station and to transport the (astronomical) data to the central processor (CEP).

The power and data cables should be routed on the site in trenches after the cabinet has been placed, because this allows finishing off the cables in a proper environment thus avoiding unnecessary damage of the cables.

The site should have at least the following minimum infrastructure:

- mains power
- data connection

4.4.1 Power infrastructure

1	The mains power cable should be routed into the container via the pipes in the foundation (annex 5.2)
2	The mains power is a 3 phase mains 230/400 V connection with a minimum of 25 A per phase.
3	The main fuses of the station are located in the container and have a value of 25 A per phase, therefore, the value of the fuse in the (public) mains distribution network to the station should not be higher than 40 A for reasons of safety (the value should be in line with the local regulations)

4.4.2 Data transport infrastructure

For the intra-station communication and the ILT station communication with the outside world a 48-port Foundry FastIron LS (FLS) switch is placed at each ILT station (ILT station switch). Via a fibre-optic cable, which must be provided by the customer, the station switch is connected to a switch which is located in customer building. This switch, which is also part of the ILT station, will be used for forwarding of the data to the LOFAR central processor to Groningen or a local data processor (ILT routing switch). Both switches will be controlled by the LOFAR system control. The connection between these switches is realized using a 10GBASE-LX based link. The fibre-optic cable (and its terminations) between the ILT cabinet and the ILT customer switch, which is used for connecting both ILT switches, must be designed, deployed and maintained in such a way that the 10GBASE-LX based link will function according to its specification.
The ILT customer must provide a 10GbE communication link, which connects a 10GBASE- LX port on the ILT routing switch to a 10GBASE- LX port on the lightpath switch at the central processor site at Groningen. The XFP's in these ports will be provided, controlled and maintained by LOFAR, as part of the ILT station. The remainder of the link (ILT connection link) should be provided, controlled and maintained by the ILT customer. For this latter link, ASTRON /LOFAR has detailed a number of availability, maintenance and security issues which are described in the table below and have to be strictly followed for a flawless operation.

The ILT connection link, which should be provided by the customer, must be a layer 2 link that supports:

- 10GbE traffic
- VLAN tagging and QinQ in case of a VLAN conflict
- The transfer of VLANs whose numbering will be determined by ASTRON / LOFAR
- IPv4 and IPv6
- 9kB Jumboframes
- Packet routing based on MAC addresses
- TCP/IP

Detailed Infrastructure and organizational issues:

1	The fibre-optic cable between the ILT station switch and the ILT routing switch must be terminated at both sides on a patch panel with SC/PC patch positions.
2	The fibre-optic cable and its terminations are configured, constructed and maintained in such a way that the ILT partner can realize a 10GbE connection via that cable.
3	The data connection between the ILT forwarding switch and the lightpath switch must be transparent regarding transport of data to the CEP. In addition, the sequence of the data as produced by the station shall not be altered, first data bit produced by the station arrives first at CEP.
4	The data connection between the ILT routing switch and the lightpath switch may not alter the data packets as they are sent out by the ILT routing switch
5	Small amounts of packet loss (<TBD packets/s) in the data connection between the ILT routing switch and the lightpath switch is only acceptable after approval of ASTRON / LOFAR
6	A high level of packet loss (>TBD packets/s) in the data connection between the ILT routing switch and the lightpath switch is not acceptable
7	The data link between the ILT routing- and the lightpath switch may not have a delay > 100 ms.
8	The 10GbE stream from a ILT station contains the following sub-streams: a. Observation mode 1 with required bandwidth: 2.7 Gbps or: Observation mode 2 with required bandwidth: 5.4 Gbps b. Monitoring and Control with required bandwidth of 100 Mbps c. Network control with required bandwidth of 10 Mbps d. Transient Mode with a varying required bandwidth which is in the order of several Gbps e. EOR mode with a required bandwidth of 5 – 7 Gbps f. Eight non-astro partner streams each with a required bandwidth of 100 Mbps Each stream will require its own VLAN. All mentioned streams will be needed in the final situation. Before upgrading at least item a, b and c need to be supported. An upgrade plan for the required bandwidth needs to be negotiated with each ILT partner.
9	Any maintenance to the fibre-optic cable between the ILT station switch and the ILT routing switch must be reported at least 1 week in advance. In case the announced maintenance does not concur with LOFAR scheduling the partner and LOFAR/ASTRON should agree a more suitable timeframe.
10	Any maintenance to the data link between the ILT routing switch and the Lightpath switch at Groningen must be reported at least 1 week in advance. In case the announced maintenance does not concur with LOFAR scheduling the partner and LOFAR/ASTRON should agree a more suitable timeframe.
11	In case of failure in the fibre-optic infrastructure between the ILT station switch and the ILT routing switch, a report must be created by the customer. This report contains an incident and a repair plan which will be provided to ASTRON/LOFAR within 3 hours after the failure has been detected. The repair plan informs ASTRON / LOFAR about the nature of the failure and the schedule for the repair. In case the problem exists for several days, ASTRON/LOFAR will be informed daily on the status of the repair.
12	The hard- and software of the ILT station switch and the ILT routing switch will be configured and maintained by ASTRON / LOFAR. The local ILT customer organization has to supply assistance in this configuration and maintenance task.
13	In case of failure of the active equipment and / or failure in the fibre-optic infrastructure in the link between the ILT routing switch and the lightpath switch, an incident and repair plan must be made. This incident and a repair plan will be provided to ASTRON/LOFAR within 3 hours after the failure has been detected. The repair plan informs ASTRON / LOFAR about the nature of the failure and the schedule for the repair. In case the problem exists for several days, ASTRON/LOFAR will be informed daily on the status of the repair.

4.4.3 Security and availability related items

The ILT customer has the responsibility to connect his equipment to the data transfer system in such a way that the LOFAR data link and connection to Central Processor at Groningen will not be endangered in any way. In case LOFAR/ASTRON notices any problems, which originate from the partner's data link, it will be disconnected. In order to prevent such a situation the following preventive measures, to be taken by the partner are strongly recommended:

1	In case an intrusion is detected in the active equipment that is placed in the link between the ILT routing switch and the lightpath interface switch, this should be directly (within 1 hour) reported to ASTRON / LOFAR (TBC LOFAR control room)
2	In case a connection between an ILT station and the lightpath switch at Groningen is suspected to be intruded/corrupted and/or is causing problems in the LOFAR Central Processor system at Groningen, ASTRON / LOFAR will disconnect this connection immediately. After the ILT partner has shown that the mentioned issues are removed / not present the link will be restored.
3	An ILT customer has the responsibility to provide a secure link in accordance with the ASTRON/LOFAR standards (TBD). N.B.: The security of the link will be assessed based on information provided by the ILT customer regarding the link between the ILT station and the lightpath switch at Groningen.
4	An ILT customer has the responsibility to provide a qualitative good link with proper availability. N.B.: The quality of the link will be assessed on basis of information provided by the ILT customer regarding the link between the ILT station and the lightpath switch at Groningen.
5	In case an ILT customer wants to connect his local data processor systems to the Internet and /or other, non-LOFAR networks, he has to install a proper firewall and intrusion detection system between the local data processor system and the Internet by that partner.

4.5 Safety

Safety measures have to be taken by the customer in order to protect personnel and equipment for:

- General personal safety
- Electrocution
- Lightning
- ESD
- Fire

It will be the customer responsibility to follow national and international standards, regulations and norms during installation and operations of the ILT station.

The table below details some, but not limited to the above mentioned issues:

1	Near the concrete foundation of the container grounding electrodes have to be driven into the ground and connected to the container structure serving as grounding connection for personnel safety and equipment grounding reference.
2	The Container grounding electrodes shall have a resistance of 2.5 ohm or better.
3	The GPS antenna needs to be protected with a lightning rod.
4	Near the concrete foundation of the container grounding electrodes shall be drilled into the ground that shall be connected to the lightning rod mounted on the container.
5	All safety and lightning grounding installation work shall be performed by a certified company and in accordance with local and/or European standards.
6	During maintenance activities that include handling of electronic boards sufficient ESD preventive measures shall be taken, such as wrist grounding straps connected to a grounding point and using ESD safe packing material.

Fire prevention:
The container does not contain any means to prevent fire or to extinguish fire. However, temperatures are measured at several places and at specific hotspots in the equipment racks. The temperatures are monitored by the LCU and passed to the LOFAR Monitoring And Command (MAC) system. MAC will give alarm messages to the operators or take autonomous actions like switching off equipment in case of emergency.

4.6 Resources and logistics

A LOFAR station installation is an intensive activity and involves a careful planning and logistic preparation. Many activities carried out by various disciplines have to be carried out in a specific order while other activities may, for efficiency reason be performed in parallel. Responsibilities for these activities may also vary and need to be discussed with the customer for the best practical and economical solution and will be determined by the final agreements and contract.
An example of an ILT installation planning is shown in Annex 5.4. Please note that planning and progress depends greatly on resource availability and experience. However, it is suggested that the customer will make use of their own staff where as possible in order to get acquainted and to gain experience with the LOFAR installation which may be very useful for future maintenance and repair work.

The following table shows a collection of particular attention during the installation:

1	A height profile carried out by geodetic measurements is required to determine the correct station rotation
2	Geodetic measurements is required to layout the pickets following the station design
3	Container must be installed on a concrete platform and require sufficient electrical grounding
4	Number of personnel typically required: • 1 or 2 supervisory (HBA / LBA groundwork and installation) • 2 + 1 crane driver for container placement • 4 groundwork including crane driver • 4 LBA installation • 5 HBA tiles (4 installation + 1 crane driver) • 3 test en commissioning
5	Sufficient and safe storage for installation tools and materials (incl. HBA tiles)
6	Sheltering and toilet in the direct surrounding for personnel
7	Catering

4.6.1 Site preparation for roll-out logistics

Suitable arrangements must be made to serve an efficient roll-out phase. Experiences in the past revealed that an area for unloading trucks containing the HBA tiles is very convenient. To withstand the frequent heavy traffic during the HBA installation at a location with a soft soil, steel road plates are highly recommended. Figure 4-1 showing an example of a typical layout for the onsite HBA unloading area at the right corner of the field.

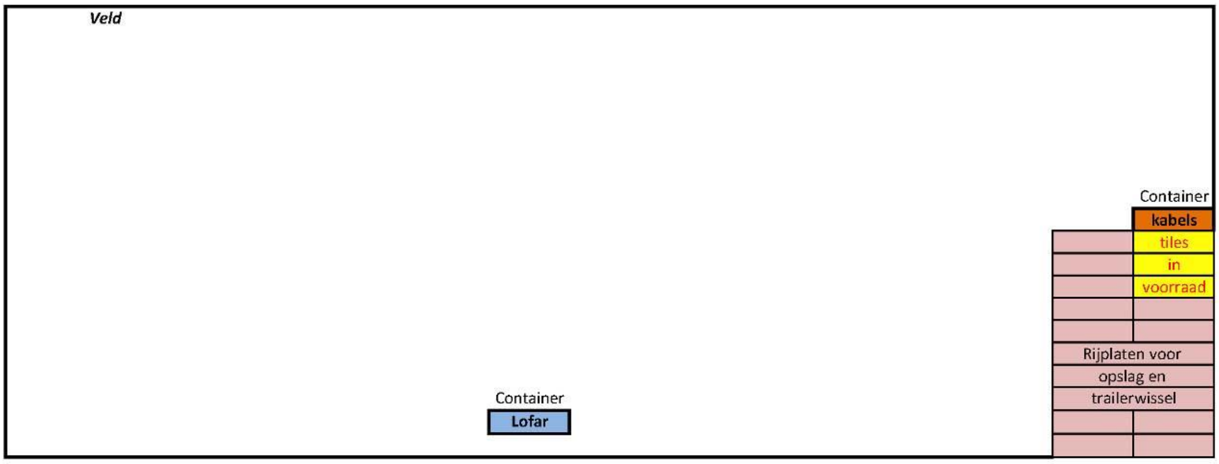


Figure 4-1 Example of an HBA tiles unloading area

Figure 4-2 Unloading HBA tiles

4.7 Deliverable items list

Most LOFAR hardware is unique and has been developed and produced according to the LOFAR specification. Where possible, COTS equipment is also used in the LOFAR system.

Table 4.7-1 presenting a summary of the hardware that a customer can expect from a LOFAR delivery package. This table only showing the items on a high level and the delivery containing more detailed parts which are not shown in this list.

Item	Number	Remark
Container with RF-shielded compartment	1	Including instrument racks and PSU's
Subrack	6	Including electronic boards
LBA LNAs, including springs and cords.	96	
LBA poles/pegs	96 sets	
HBA tiles	96+1	1 dummy tile
LBA Coax cables	192	Different sizes
HBA Coax cables	192	Different sizes

Table 4.7-1, hardware overview (at a high level)

For some of the hardware parts it is more economical to acquire these locally instead of shipping these parts from ASTRON/LOFAR in The Netherlands. Options for these parts will be discussed and agreed in the final contract. Table 4.7-2 showing an example of parts and equipment that can be organised by the customer.

Item	Number	Remark
LBA ground plane mesh	96	Steel mesh wire generally used for concrete reinforcement
LBA ground plane foil	96	Plastic foil generally used by gardening
Splice box including optical modules	1	
Power connection	1	
Data connection	1	

Table 4.7-2 Hardware overview which can be acquired locally

5 Annexes

5.1 Annex 1 Reference site layout (examples)

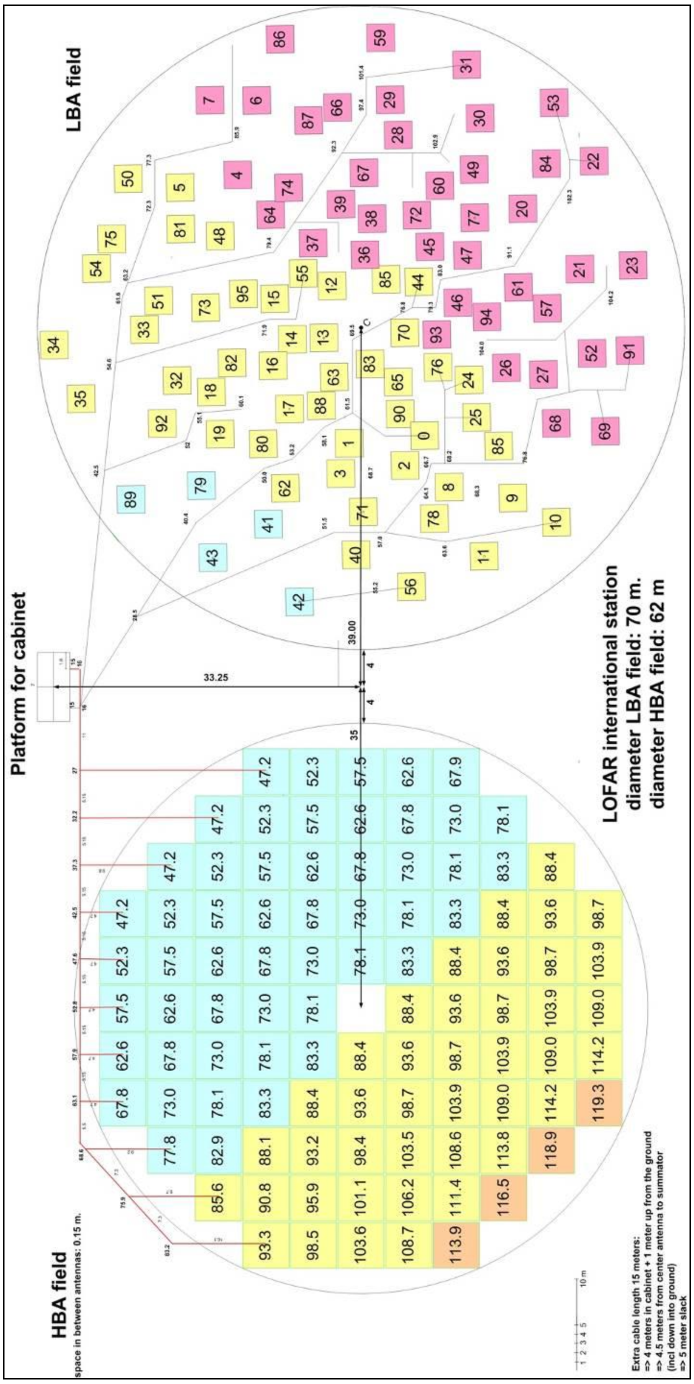


Figure 5-1 LBA and HBA layout

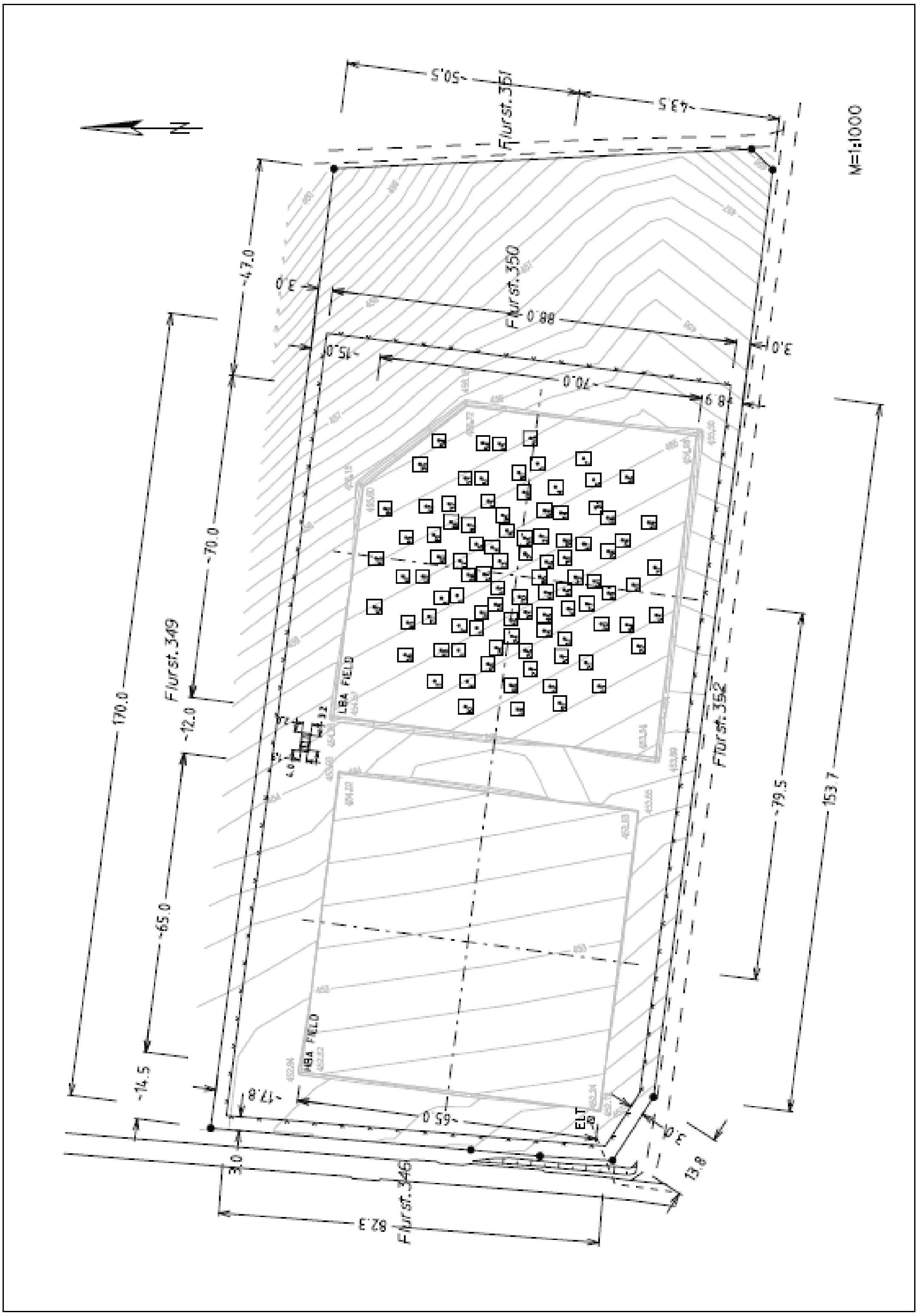


Figure 5-2 Example LBA design drawing

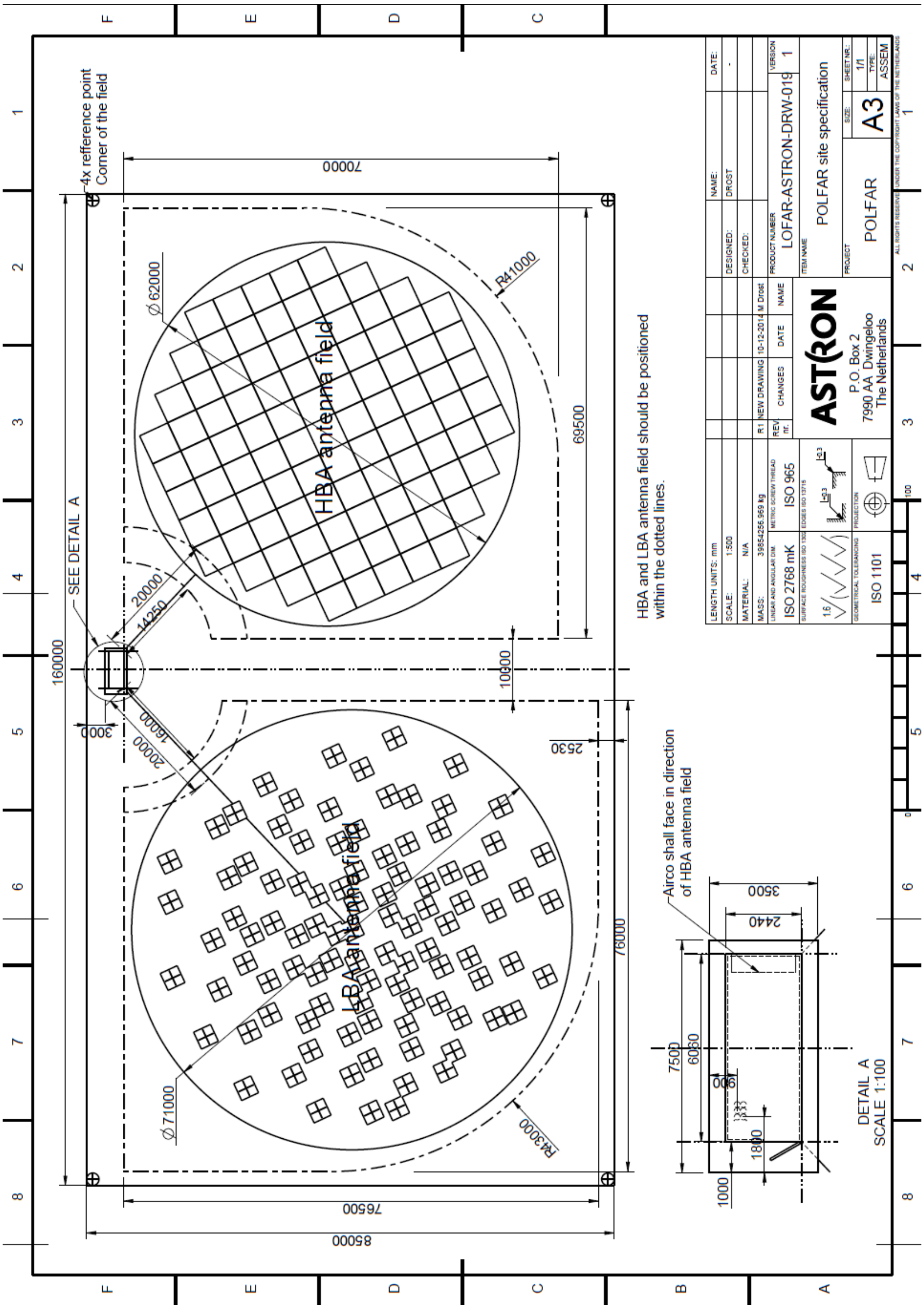
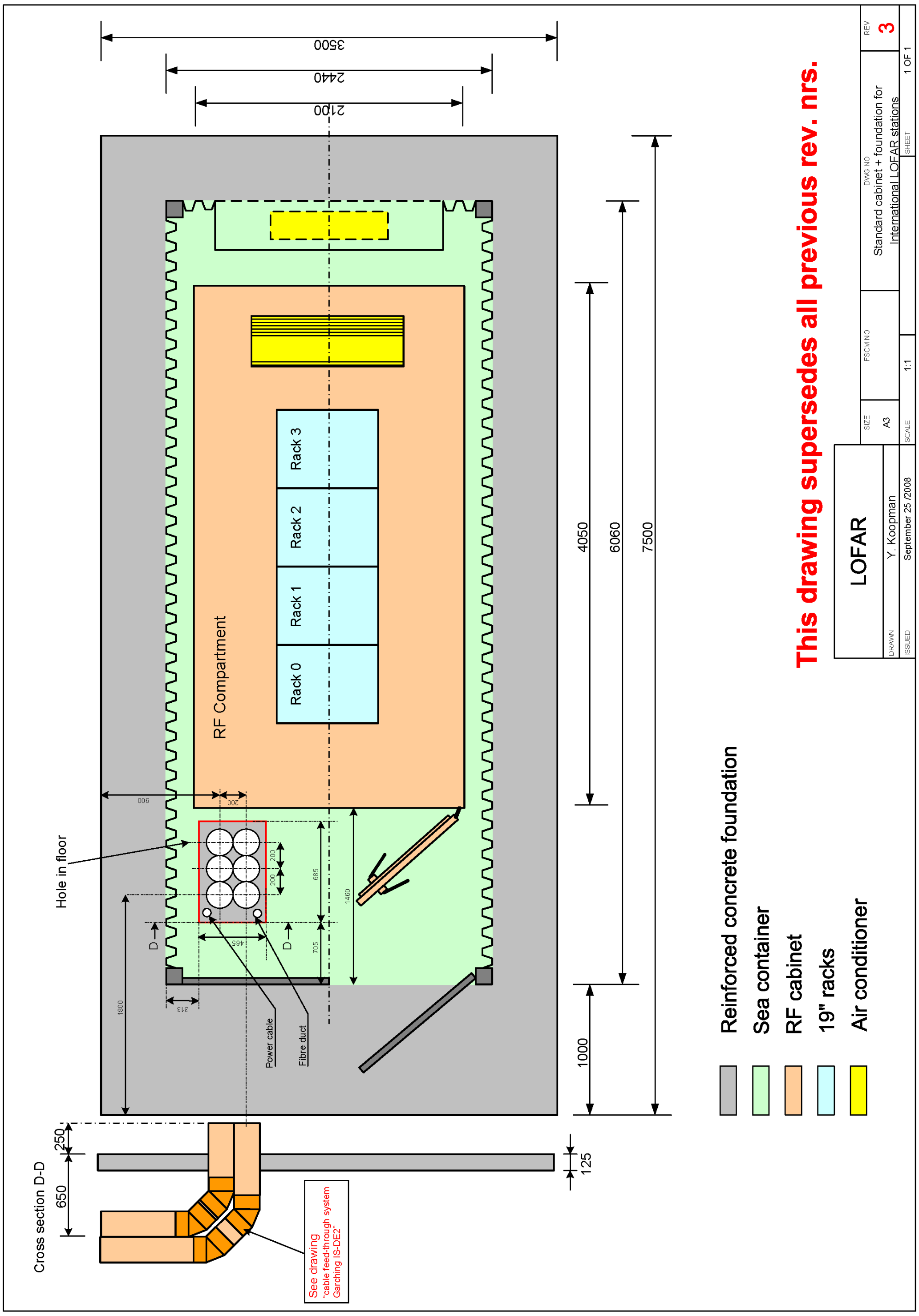


Figure 5-3 POLFAR site specification drawing

5.2 Annex 2 Container foundation drawing



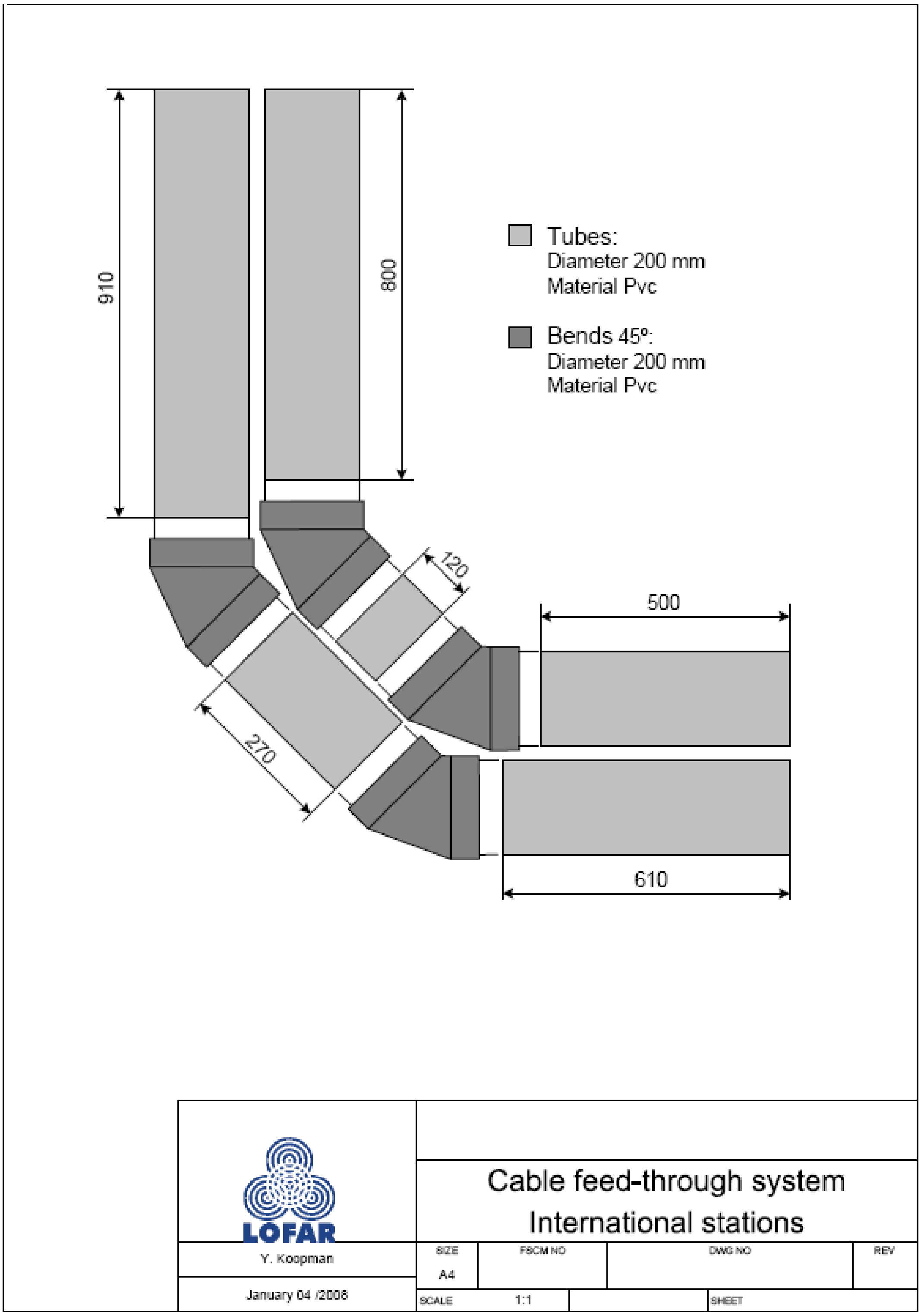


Figure 5-4 Container cable feed-trough tubes

5.3 Annex 3 LOFAR LBA and HBA construction

A short information about the LBA and HBA hardware is presented in the following pages. Detailed technical information and specification can be found in RD.10. The following figures showing a section of a LBA and HBA array respectively.

Figure 5-5, LBA array

Figure 5-6, HBA array

Low Band Antenna

The Low Band Antenna (LBA) consists of two perpendicular inverted-V shaped dipole antennas and two active baluns, integrated on a single pcb, to provide amplification and impedance transformation. Each dipole arm has a length of 1.38 meter, resulting in a resonance frequency of 58 MHz. Received signals of both polarizations are transported to the station cabinets via two coaxial cables. The active baluns are powered via the same coaxial cables. Mechanically, the antenna consists of a centre pole that is kept upright by four (antenna) guy wires and has a total height of 1.7 meter. Both coaxial cables run through the centre pole. One end of the lower parts of the two (perpendicular) antenna wires consist of rubber springs. The lower parts of the other two wires are made of polyester cord. For protection reason, the active baluns are encapsulated into an epoxy or polyurethane block by PCB potting (Figure 5-9). This block is located at the top of the centre pole. A welded wire mesh of 3x3 m (mesh pitch 15 cm, wire thickness > 5 mm) is located under the antenna to form a ground plane. To prevent vegetation growing through the ground plane, a plastic foil (also 3x3 m) is placed underneath the metal ground plane as an option. The guy wires are connected to four tent pegs. The dipoles have an inverted-V or pyramid shape and are placed under a 45 degrees angle to broaden their beam width in the E-plane (Figure 5-7).

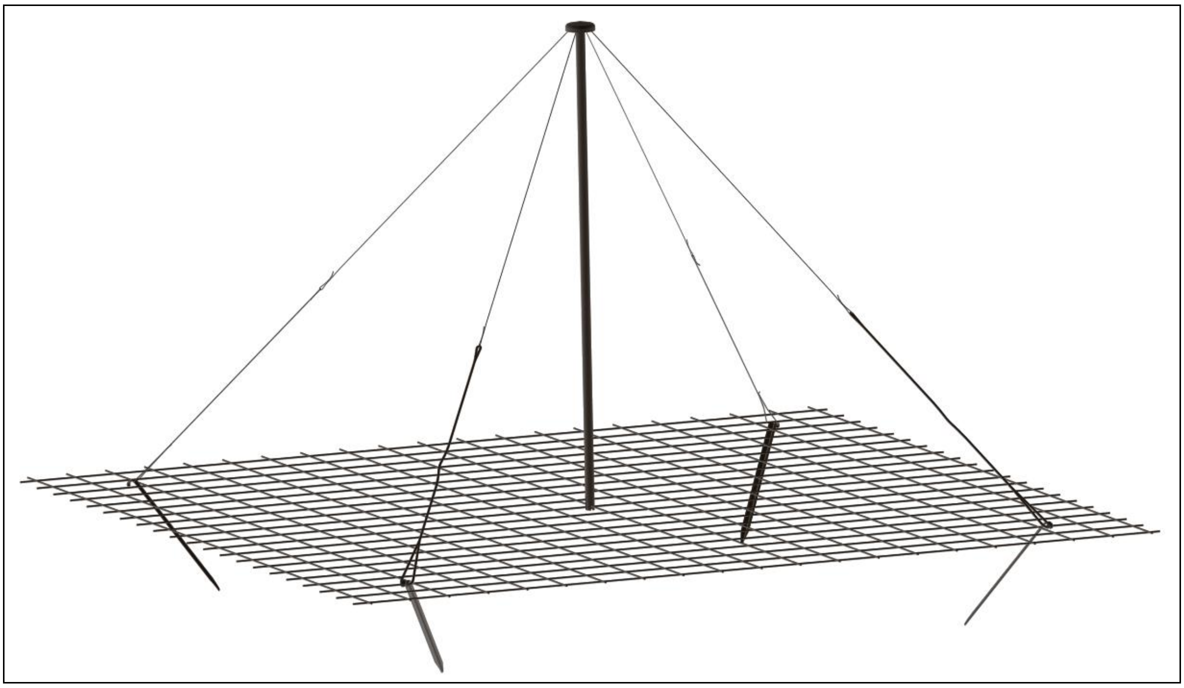
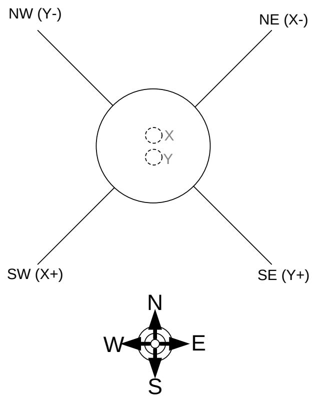


Figure 5-7, LBA construction

When the LBA is placed in an array configuration, polarisation and orientation of the single LBA are very important. Figure 5-8 shows the top view of a LBA antenna, together with the north direction. The PVC pole is placed perpendicular to the levelled ground plane of the LOFAR station (96 LBA antennas). With this configuration the x polarisation of the F-connector is located to the north direction (red/orange F-connector in Figure 5-9).

A complete international LBA array of 96 antennas measures approximately 70 meters in diameter.

LBA orientation



Top view

Figure 5-8 LBA Orientation

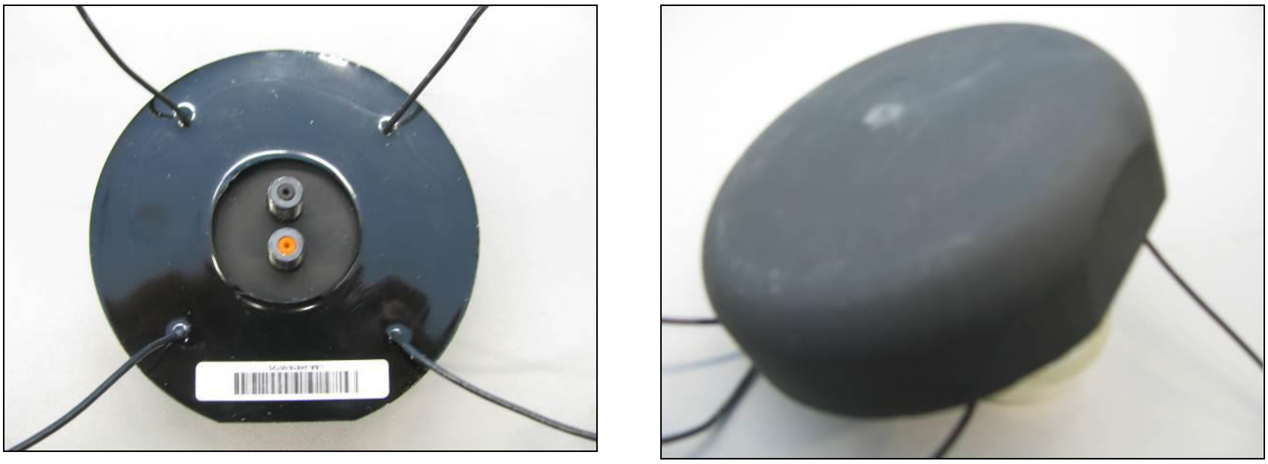


Figure 5-9, LBA active BALUN

High Band Antenna

An international HBA array consists of 96 tiles and one (passive) dummy tile. One tile is constructed from various specific designed and produced EPS (polystyrene) blocks with a metal wire mesh forming the antenna ground plane (Figure 5-10). This construction is covered with a plastic top and bottom sack.

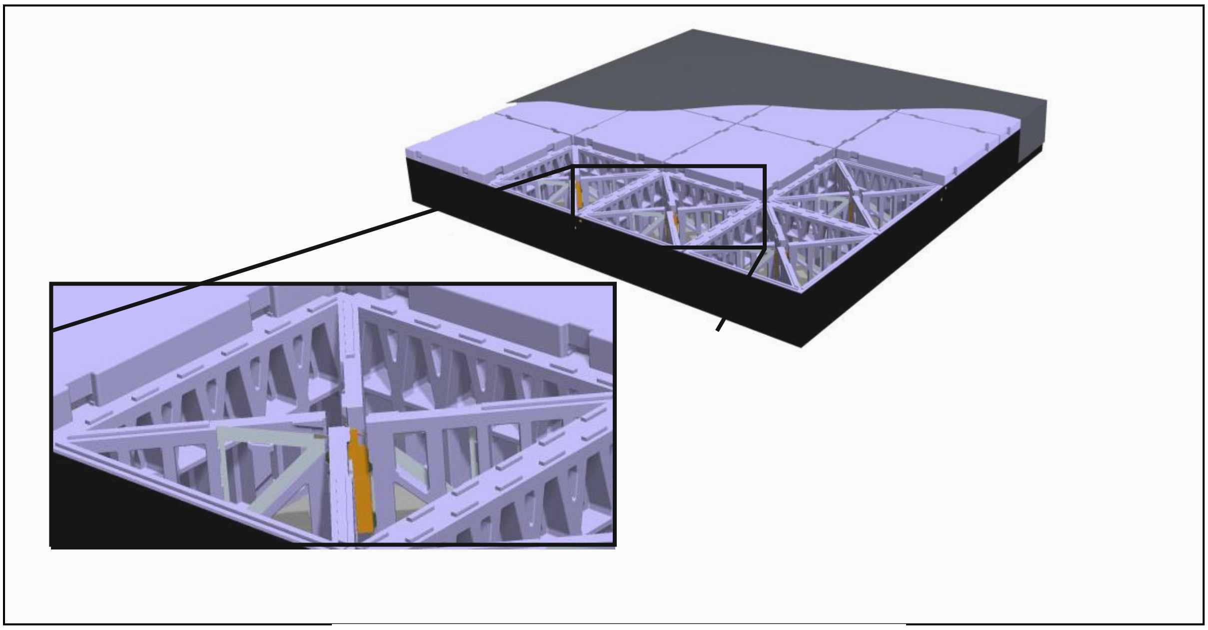


Figure 5-10, HBA tile

The sacks will protect the EPS construction and electronics for the harsh environmental conditions and will be used for anchoring of the tile.

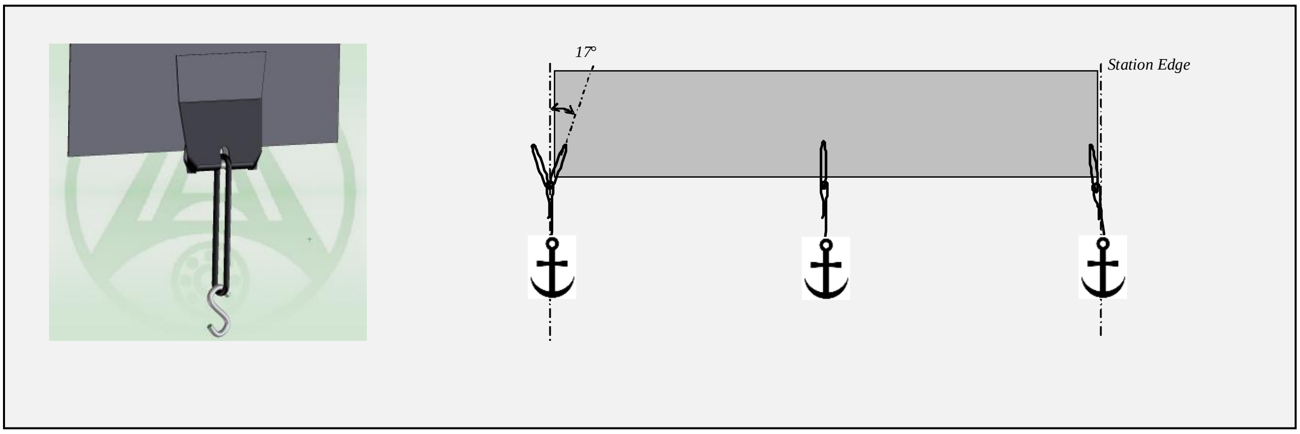


Figure 5-11, tile anchoring

Each tile housing 16 dual polarized dipole antennas and 16 low noise amplifiers (HBA-FE). The signals from the 16 antennas are combined in a summator unit. There are two summator units in a tile, one for each polarization. Each summator is connected to a coaxial cable carrying the received RF signal from each polarization. Via one of these coaxial cables and the summator (P-summator), the 16 HBA-FE's are DC-powered. Control and status signals to and from the HBA-FE's are transported via the second coaxial cable and summator (C-summator). Figure 5-12 showing an example of the C-summator unit.

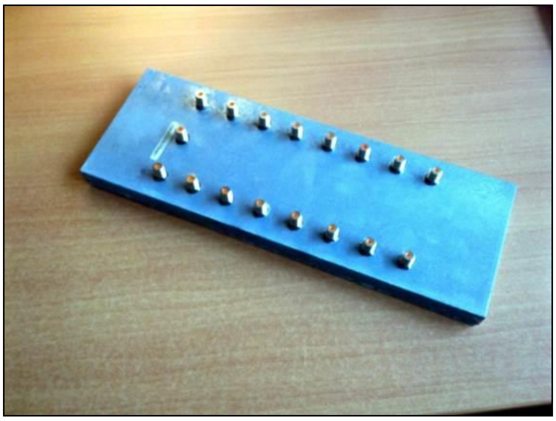
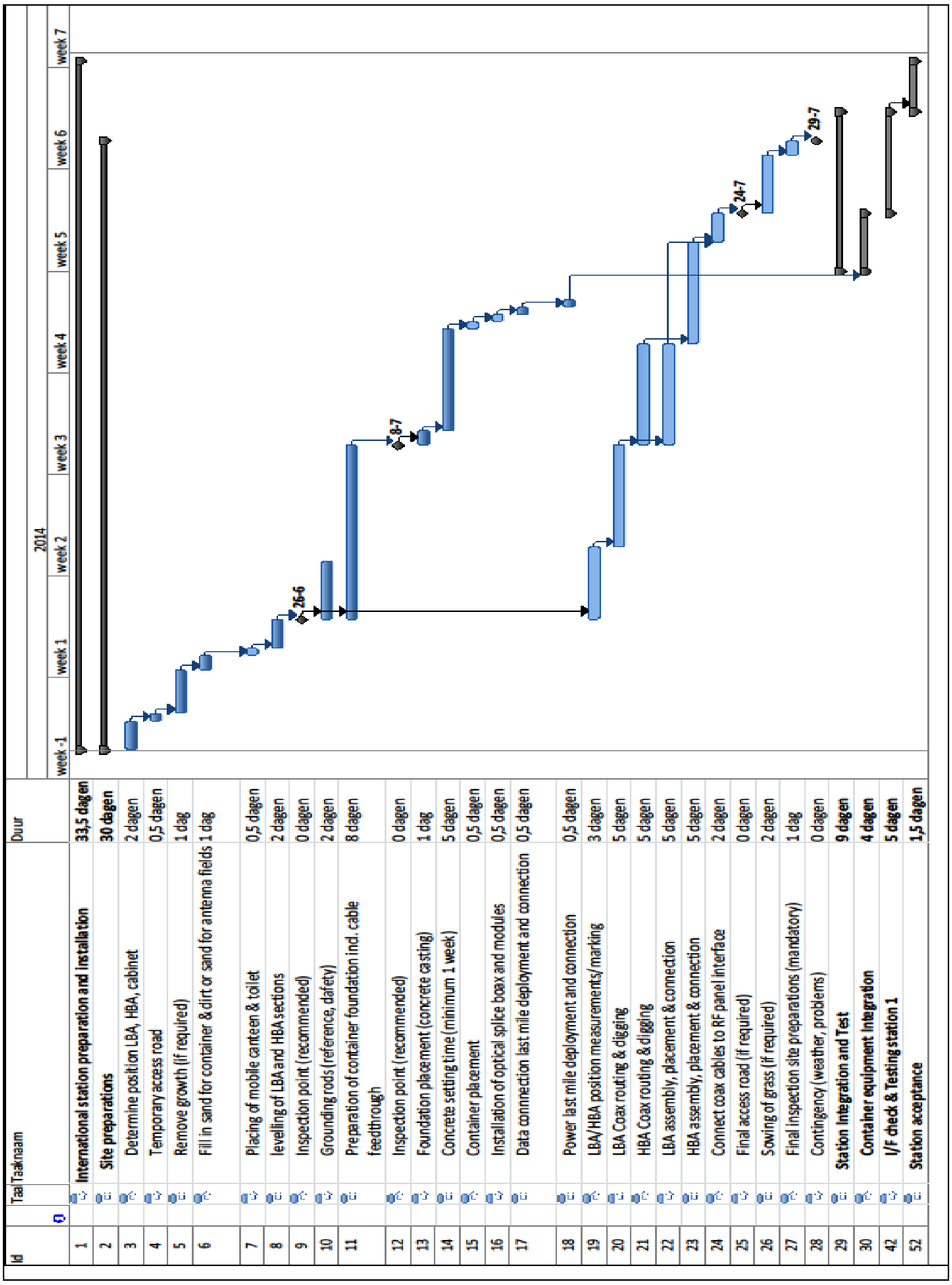


Figure 5-12, C-Summator for LOFAR HBA

An international LOFAR station is formed by 96 active HBA tiles. For symmetry reason a dummy tile is installed in the centre of the array. This dummy tile consists of a ground plane and dipole antennas but no active electronics (HBA-FE) are installed.
Tile dimensions are approximately 5 x 5 x 0.8 meter. The total HBA array measures roughly 62 meters in diameter.

5.4 Annex 4, example of a LOFAR installation planning

This is an example of an ILT installation planning. Various items and circumstances such as logistics, weather etc. will have an impact on the overall planning. The planning is therefore subject to discuss in more details with the customer.



5.5 Annex 5 LOFAR station installation

The following pages serve as an example for the installation of a LOFAR station. Experience from the Dutch stations roll-out is used as a reference. For international stations the installation maybe changed due to the local situation. Details can be discussed prior to the final roll-out plan.

Equalizing ground

TBW.

Container installation

A stable support is required for the LOFAR international container holding the back-end equipment. The type of support is depending on the local situation. Most often a concrete base will be used as a solid support. Cable ducts will also be required to feed through all the coaxial cables, power lines and network cables.

Figure 5-13, concrete base and container installation (Courtesy of UK608)

Figure 5-14, container as will be used for ILT stations

LBA Configuration

The following figure showing the configuration of the Low Band Antennas for an international station. The distance between the antennas vary. This configuration of the 96 antennas must be rotated with an angle which will be delivered at the time of installation.

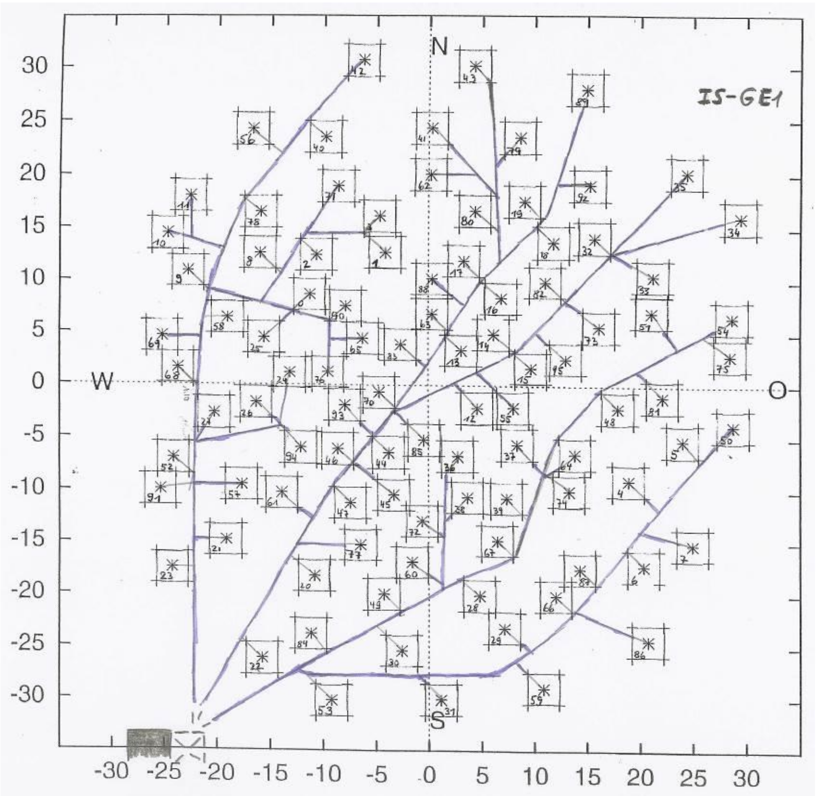


Figure 5-15, LBA configuration (scale in meters)

The individual antenna position accuracy is plus or minus **6 cm** (see section 2.1.3). After placement of the antennas, all positions must be measured (again) with an accuracy of **1 cm**. These positions will be fed into the station software. All antennas are connected to a central cabinet with coax cables up to 110 meters. Each antenna has two of these cables, making the total number of 192 cables. The cables are placed in 60 cm deep trenches (see section 2.1.3. for specifications) but other options can be considered.

<u>LBA installation</u>

The following photos showing the LBA installation in a sequential order:

<u>Step 1</u>

Trenches are made according to the station design drawing.

All coaxial cables are rolled out inside the trenches towards the container.

A small crane making the trenches for the coaxial cables as marked by the wooden pickets.

Step 2


The two cables are placed and the ground is made flat again (by hand).

Step 3

A foil* of 3x3 meter is placed. A small hole for the two cables in the middle is made. The orientation is marked by the North position picket.

Step 4

The ground plane is placed on top of the plastic foil.

Step 5

The 2 coax cables are fed into a LBA antenna pole.

Step 6

The antenna is connected to the two coax cables. There is a collar in the LBA potting that will fit the tube.

Step 7

The tube has little slots in the bottom that make a perfect fit to the grid of the wire mess. At the bottom, the two coaxial cables have some overlength for (dis)assemble of the LBA.

Step 8

The 4 tension cord/springs are connected to 4 ground pegs, one at each corner.

Final result of a raised LBA

HBA Configuration

An international station consists of 96 HBA tiles and 1 dummy tile (dummy tile is not shown). Each tile is approximately 5 x 5 meters is size. The tiles are installed with a corner lined-up with a predefined position indicated by a picket. There is a small gap of 15 cm between the tiles. The tiles are laid-out following a specific station rotation in the station design. Each tile, except for the dummy tile is connected by two coaxial cables. Generally 3 different cable lengths (as indicated by different colours) are used for the connection of each HBA tile.

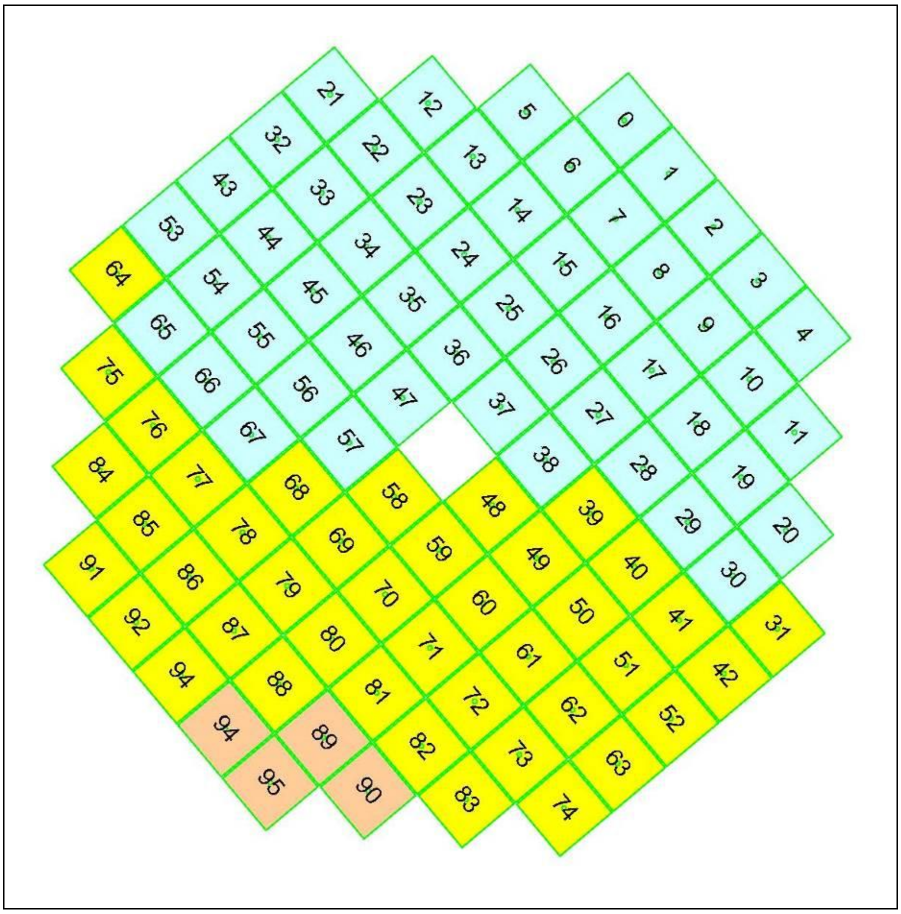


Figure 5-16, HBA configuration

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HBA installation

The following photos showing the HBA installation in a sequential order:

HBA-tile marking and ground anchors installation.

HBA-tile transport from storage trailer to installation position. (Note: POLFAR roll-out will not be executed in this manner)

Lifting and unfolding HBA tile

Positioning HBA tile (Note: POLFAR roll-out will not be executed in this manner)

Connecting coax cables and placing top cover

HBA final installation result (ILT SE607, Onsala)

5.6 Annex 6 Inspection checklist

The parameters in the following checklist can be used for the evaluation of the site and to what extend the proposed site is suitable for hosting a LOFAR station. In case the outcome of the inspection is "less suitable" it means that corrective measures must be taken in order to improve the situation.

LOFAR Site preparations checklist

Customer: ……………………………………………………

Station location: ……...

Station name/number: ……..………/………….

Date of inspection: ……

LOFAR representative: ……..

Customer representative: ……………….

Items to be checked during the inspection:	Yes	No
1. Is the site evaluation checklist of section 3.1 completed and agreed?	❑	❑
2. Is the EMC evaluation checklist of section 3.2 completed and agreed?	❑	❑
3. Are the field preparations completed and agreed, see section 4.2?	❑	❑
4. Are the Infrastructure elements available, see section 4.4?	❑	❑
5. Are the Safety measures completed and agreed of section 4.5, including grounding resistance measurement report?	❑	❑
6. Are problem reports and deviations available? (if applicable)?	❑	❑
7. Are the antenna position measurement results available?	❑	❑