# LOFAR

## Low Frequency Array

# LOFAR International Site preparation 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 who have the intention to purchase a LOFAR station. The document forms a source of information upon which can be decided if a location is more or less suitable to build a LOFAR station. In order to arrive at 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.


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| 1.1 | January 2008 | All | All | Changing scope |
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**Table of contents:**

# 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 more or less suitable to build a LOFAR station. In order to arrive at 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, placement and installation of equipment, resources needed.

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 suggested that the customer sends a representative to LOFAR/ASTRON in order to familiarize with the LOFAR equipment and to get hands-on experience regarding installation and maintenance of a station.

## 1.1 Scope and limitations

The purpose of this document is to assist with the search for potential LOFAR site locations and for planning of site preparation work in case the search proved to be positive. Specific issues, in particular the lay-out of the antenna fields and the RFI conditions, of the selected LOFAR site locations will be different with regard to 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.

This specification does not cover aspects like:

- Cost issues
- 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 towards Potsdam (~EW) and Limburg (~NS) add significantly to the spatial sampling for the astronomy applications. Longer baseline European extensions are possible as well (e.g. towards existing astronomical observatories like Onsala, Effelsberg, Tautenburg, Chilbolton and Nançay).

The ICT infrastructure of LOFAR holds 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 geoscientific measurement data. The following are some of the activities the geoscientific participants in the consortium will be involved in:

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

In the Core area, with 2 km in diameter, there will be a minimum of 18 stations; each station will consist of Low Band and High Band Antennas. The number and configuration of geophones, hydrophones and micro barometers in the Core area is yet to be defined. Selected stations will be equipped with additional sensors for the agriculture application.

Each Remote Station will be equipped with High Band antennas, Low Band antennas, seismic sensors, micro barometers (for infrasound detection) and several auxiliary systems e.g. for weather monitoring and GPS time/position measurements.

Remote stations will be connected by 10 GbE technology to the Central Processing systems (CEP). The sensor data will be dominated by the astronomical antennas (about 2.2 Gb/s, being the equivalent of a single dual-polarized beam over 32MHz, so 1x32MHz or 8x4MHz etc). For the astronomy application, full Tied Array beam forming will be supported. Transient detection will be 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 datarate is equivalent to the stations in the Netherlands, about 2.2 Gb/s of sampled data and somewhat 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 30 degrees elevation.
- 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 FM transmitters.
- Broadband 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 32 MHz. Each Remote Station delivers a single dual polarized beam at 32 MHz, or 8 dual polarization beams at 4 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 |
| E-LOFAR | International LOFAR Station |
| EMC | Electro Magnetic Compatibility |
| EoR | Epoch of Re-ionisation |
| HBA | High Band Antenna |
| HW | Hardware |
| 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 |
| 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 shall 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 |
| AD.5 | LOFAR-ASTRON-PRC-004 | 1.0 | LOFAR Change Control Procedure |
| AD.6 | LOFAR-ASTRON-MEM-231 | 1.0 | LOFAR cabinet spurious emissions measurements above 300 MHz |

### 1.5.2 Reference documents

The following list of reference documents provide 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 |

# 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
- 1 modified sea container that includes an RF tight section for station electronics

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

The sensor fields contain the following sensor types:

- One astronomical sensor field (the LBA field) contains up to 96 LBA antennas
- The other astronomical sensor field (the HBA field) contains up to 96 tiles containing each 16 HBA antenna elements.

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 |
| Modified sea container with 4 x 19” racks containing all station electronics (detailed in chapter 2.1.1) | 1 |
| Coax cables to LBA field | 192 |
| Coax cables to HBA field | 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. However these are general pictures. The LBA, HBA and Non-Astronomical field positions may depend on the site dimensions that are locally available. Each site will be different in size and will be oriented in another way and therefore the sensor layout for each site shall be determined specifically and mutually agreed between the LOFAR applications. 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. For scientific reason, it is preferable to place the container north of the antenna fields to avoid obstructing the view to the southern horizon. RFI properties of the container do not play a role in the layout considerations, because the supplied container will be RF tight i.e. the RF attenuation is > 80 dB over a frequency range of 100 kHz to 10 GHz. (The optional NAA cabinet should have an attenuation of > 40 dB over a range from 100 kHz – 300 MHz.)

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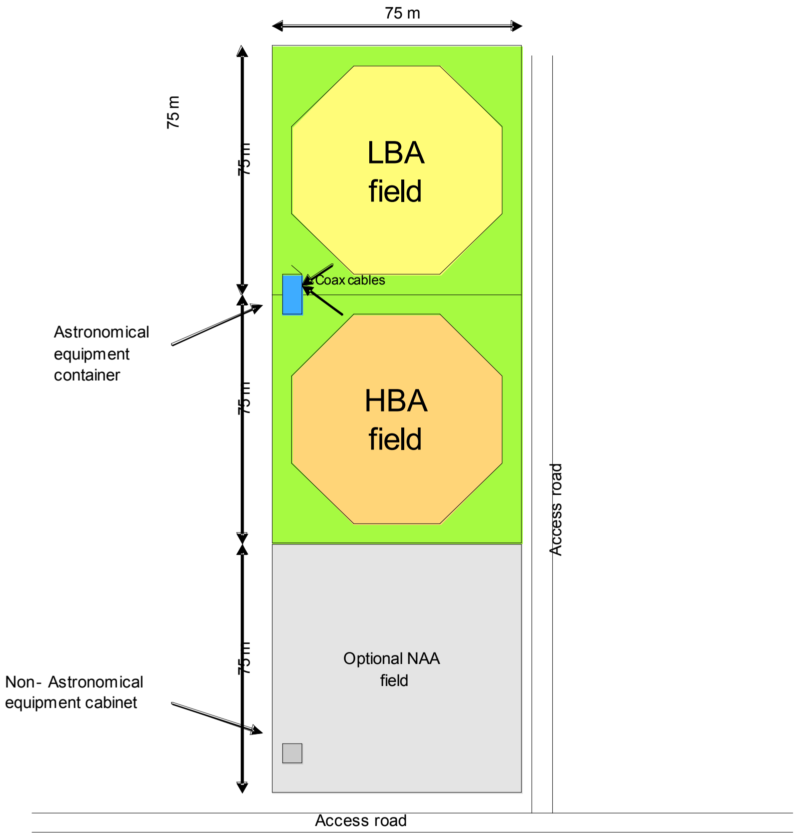



**Figure 2-1 Remote station layout example 1**

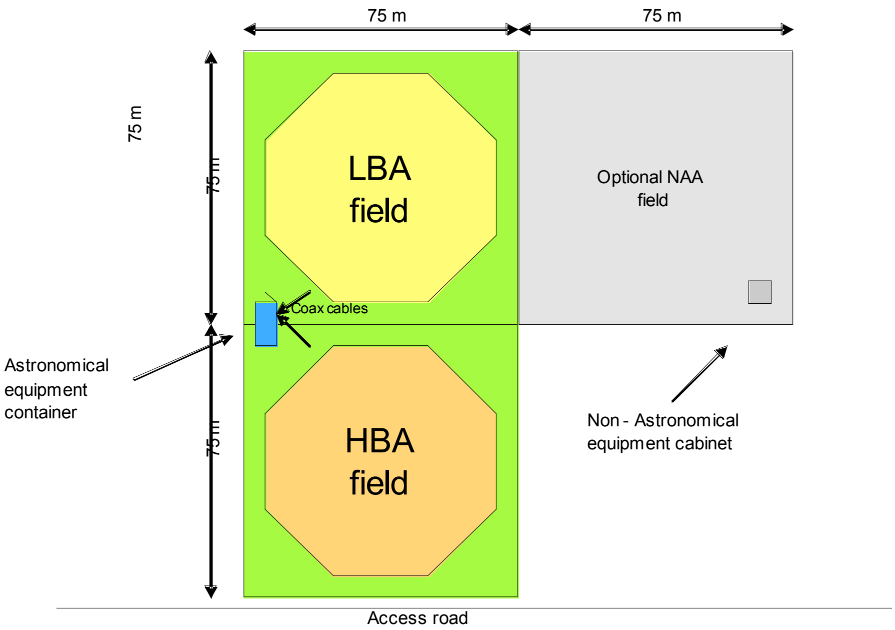



**Figure 2-2 Remote station layout example 2**

### 2.1.1 Station electronics

The station electronics will be housed in an RF tight compartment that is part of a modified sea container. In the RF tight 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 in their operational range.
The container has the following provisions and 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: | In consultation with ASTRON/LOFAR |
| - Operation temperature range: | - 20 ºC to +40 ºC |

The container 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 the drawing in annex 5.2. A more detailed description of the container can be received upon request will be part of the station documentation.

**Station electronics compartment in container**
The LOFAR station electronics is contained in four interconnected 19” racks. The first three racks contain receiver subracks and the other rack holds the control equipment, time reference equipment, switches and the power supply. The building practice is 19”.

**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:**
- 3 phase mains filter
- mains power distribution panel
- Power unit (+48V DC)
- LCU (Local Control Unit)
- Two Ethernet switches, including fibre modules
- Glass fibre termination/splice unit
- GPS receiver
- Rubidium clock

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)

### 2.1.2 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 (TBC)

| | |
|---|---|
| Maximum power dissipation in container (excluding air-conditioning): | 8.8 kW |
| Maximum power dissipation/consumption antennas LBA + HBA: | 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:**
Delivered in standardized lengths including connectors: ranging from approx. 50 up to 130 m, Coax-9 cable, F-connector

### 2.1.3 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
- 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
- Footprint rotated by certain angle from station to station including correction for longitude and latitude. Reference: Effelsberg, 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 E-LOFAR 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:**

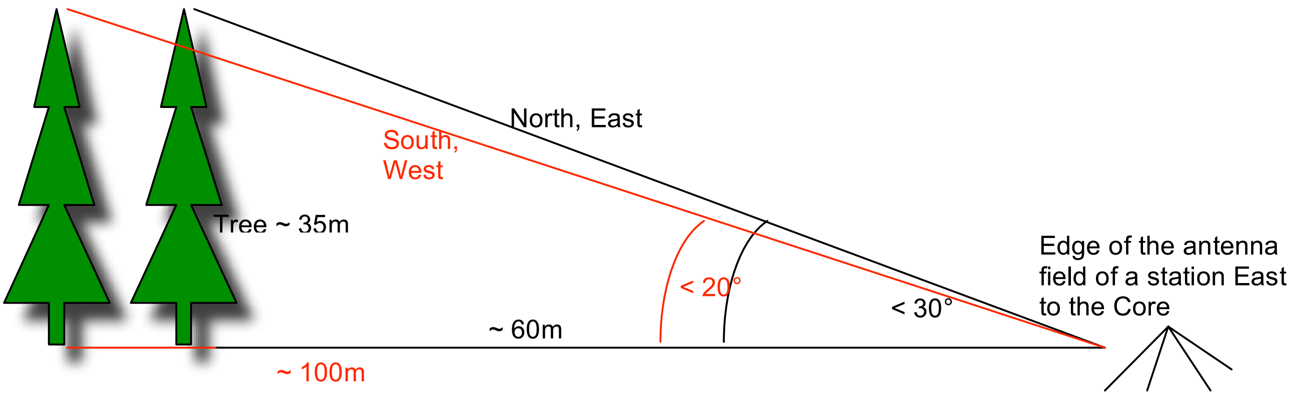
| | |
|---|---|
| - Nominal field size: | approximately 75 x 75 m. square. |

- Amount of HBA tiles: 96
- HBA tile size 5 x 5 m
- Intertile distance 60 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 (now and in the future). A station site is preferably located in a fairly isolated place which is 2 km remote from overhead power lines nearby and relatively far from any highways, roads with heavy traffic, railroads or tramways. It is also not located nearby villages or towns. High windmills used to generate electrical power will also influence the station performance if located within 2 km. It should be investigated if no other radio interference sources are present in the neighbourhood.

The station is best located in a rural area or in 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, because nearby trees or structures higher than 20 m will influence the maximum viewing angle of the antennas (based on a desired minimum elevation angle of 10 degrees).




In conclusion, the trees or a dense forest might block the field of view of a LOFAR station down to low 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 view 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 depicted in figure above. Note that the distances depend on the height of the trees.

Please note that it will be necessary to bury the cables in trenches with a nominal depth of 60 cm and therefore it is recommended that the land to be acquired should be declared free of any potential archaeological findings. The depth can be adjusted to the local situation of the soil. Burying the cables will prevent damage by e.g rodents or maintenance equipment.

## 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 2-1and 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 should be as horizontal 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). 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.

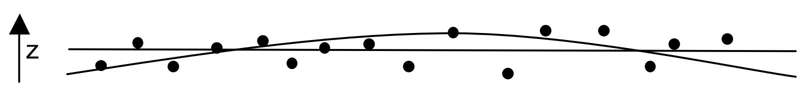
A threat for the coax cables that are buried in the ground is a rocky soil, sharp rocks may damage the cables and either protection or local removal of the rocks is recommended.

## 2.4 Station lay-out specification justification and background information

**An E-LOFAR station field**

In the course of the re-scope discussions, it was recommended that an international LOFAR station also called “E-LOFAR 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 artifacts.

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 E-LOFAR station (see chapter 2.1.3). The antennas should be erected normal to the plane.

**E-LOFAR Antenna footprints**

*LBA Outlier dipoles*
During the re-scope discussion, the concept of the outlier dipoles has been introduced. These were suggested to support station calibration of the re-scoped core and remote stations, as it seems difficult to calibrate a 48 LBA station. In addition the CR application can profit from these outlier dipoles as it increases the footprint of a station.

However, for an E-LOFAR station 96 LBAs are planned. Such a station can be calibrated without outlier dipoles. The Cosmic ray application does not benefit for the E-LOFAR station from the larger footprint. In addition it is easier to place the antennas and the electronics (i.e. the cabinets and cables) without outlier dipoles. Thus, it is suggested to abandon the idea of outlier dipoles for E-LOFAR stations.

*LBA field layout*
The 96 LBAs will be placed in a random fashion following the layout in Figure 5-1. 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 60 cm. The final HBA tile station layout needs to be confirmed by tests that are ongoing.

*Rotation of antenna fields*
The far side lobes of the station beam are a concern for 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 E-LOFAR 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 chose 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 E-LOFAR station, it is suggested to use its layout and antenna/dipole positions as reference.

As the determination of the rotation angle could lead to misunderstanding it is proposed that the LOFAR project will determine the location of the antenna taking the described above into account and send them to the various E-LOFAR stations.

*Parallel dipoles*

For the core and remote stations it has been advised to place all dipoles parallel to each other. This is on the one hand in support of calibration and on the other hand important for the tied array beam forming. At the distances of E-LOFAR stations it is no longer possible to have the dipoles parallel. On the one hand due to the curvature of the Earth and on the other allowing for inclined planes with levelled antennas.

The advantage of having the dipoles as parallel as possible to each other across stations is that it simplifies calibration.

## 2.5 Non-Astronomical applications (optional)

The optional third sensor field can contain e.g. sensors like geophones, hydrophones and infrasound sensors (such is the case for the Dutch 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 an other application on or near a LOFAR 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 in section
- 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.
- The optional NAA cabinet should have an attenuation of > 40 dB over a range from 100 kHz – 300 MHz.
- A non-astronomical application partner is given the opportunity to transfer the data from its equipment at a specific E-LOFAR site via the E-LOFAR 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 required to be taken by the partner:
        - Installation of a firewall and intrusion detection system between the VLAN or the E-LOFAR station site systems and the Internet and /or other, non-LOFAR networks, which comply with the requirements of ASTRON / LOFAR
        - ASTRON/LOFAR will assess, together with the partner, the firewall and intrusion detection system, before the partner systems are connected to the ASTRON / LOFAR systems and also (regularly) during their connection to the ASTRON / LOFAR systems.
        - To avoid problems in the E-LOFAR data link, the partner must configure his traffic and link according to the guidelines provided by ASTRON/LOFAR
        - In case a partner detects an intrusion in one of his E-LOFAR systems, this should be directly (within 1 hour) reported to ASTRON / LOFAR.
        - To avoid problems in the E-LOFAR data link, only traffic and communication standards may be used that are compatible with the LOFAR network. For this ASTRON / LOFAR will provide specifications
    - 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 E-LOFAR 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 chapters in this section provide a set of basic issues that should be fulfilled in order to allow installation of 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 impact on the performance. The goal should be to satisfy as many of these items as possible and in that case the station performance will be adequate.

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

## 3.1 Site evaluation check list

This chapter provides the basic desired properties of the physical location and the site that will be favored for installation of a LOFAR 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 more or less impact on the performance is possible. In case all statements below can be checked positively the performance will be best, if none of them are met the situation will have to be improved with certainty. Consultation of LOFAR specialists may be required to indicate which points need 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. | The draining of the site is such that (rain) water does not form puddles on the ground planes of the LBA for periods longer than 30 minutes after a period of heavy rainfall. Water on the ground planes will change the performance of the LBAs. | |
| 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 2 km of any windmills in specific windmills used to generate electrical power. | |
| 8. | The station is not located within 500 m of any highway or roads with heavy traffic | |
| 9. | The station is not located within 500 m of any urban 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 south viewing border is cleared of 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, except the sensor electronics, is installed inside shielded outdoor cabinets. The level of shielding is sufficient for the LBA, HBA. The maximum emission level for 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]. This standard cabinet provides 40 dB shielding and it is used for all sites in the Netherlands.

However, international stations are more often than not located on sites owned by scientific institutions where more sensitive sensors are present, such as large radio telescopes. Therefore a (certified) container is the standard option for sensitive sites. It provides sufficient shielding in the frequency range of 100 kHz up to 10GHz with an attenuation of > 80 dB.

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 necessary anymore. Only a responsible person and documentation of the station is necessary. A LOFAR installation complies with all applying CE requirements.

| 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 LOFAR, a number of issues will have to be taken care of by the customer in order to prepare for the installation of the LOFAR station. These points are discussed in the following sections. In annex 5.5 an example illustrates how to build a LOFAR station in Dutch conditions.

The preparation will be declared finished after an evaluation by both the customer and LOFAR/ASTRON personnel and upon mutual agreement of the work that has been performed. A standard checklist and a suggestion for the agenda of the evaluation meeting is contained in annex 5.6.

## 4.1 Overview of support tasks

This chapter provides an overview of the support tasks of the customer and ASTRON/LOFAR. It serves as an indication of the boundaries of the responsibilities of both parties, but has not the intention to specify all binding conditions. The latter will be agreed in the contract.

The baseline will be that the customer will support LOFAR among other by performing site preparation work, where the following points are highlighted below:

- Site acquisition (RFI is a selection criterion, that has to be discussed with LOFAR)
- Site preparation (ground work)
- Placement of a concrete container foundation including cable feedthrough pipes
- HBA tile and LBA antenna placement including routing of coax cabling (in trenches) up to the container
- 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
- Support during operations and maintenance
- Providing the hardware mentioned in Table 4.5-1.
- Gluing of cable feedthrough pipe from delivered parts

In addition the customer will be responsible for safe working conditions for ASTRON/LOFAR personnel on the site in preparation and in related buildings.

Responsibilities during phases for ASTRON/LOFAR:

- Delivery of LBA parts, HBA tiles and parts, see Table 4.5-2
- Delivery of container including equipment, see Table 4.5-2
- Integration of rack equipment in container
- Testing, concluding with acceptance
- Remote operations
- Astronomical data delivery
- Maintenance (preventive, corrective) (To be agreed in separate maintenance contract)
- Providing the Data Delivery Package (contains all relevant information regarding the delivered station)

## 4.2 Field preparation and equipment placing

Field preparation is an important issue and the customer is asked to carry out this work, gaining valuable experience regarding the preparation and installation of a LOFAR station.

The table below contains the more detailed steps that have to be taken in order to prepare for the installation of:

- HBA and LBA field preparation
- Container foundation and 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 2.1.3 and by considering the additional points mentioned in chapter 2.4. |
| 2. | Coax cables have to be buried as protection against people, vehicles, rodents and for better temperature stability. A nominal depth of 0.60 m 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 before the installation of antennas starts. |
| 3. | Coax cables have to be handled carefully in order to allow all antennas to operate nominally:<br>- personnel should not walk or stand on the (bare) cables (make trenches not too wide)<br>- cable overlength should be buried in large loops without coiling of the cable<br>- sharp bending should be avoided (bending radius not less than 10 cm)<br>- connectors should be protected always against dirt and water until connection<br>- 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 (when available), 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 lay-out. |
| 5. | The position and orientation of the container should be determined and marked as guided by the site specific drawings (when available), taking into account the specific form and dimensions of the site at hand, see section 2. In general can be said that the cable entry openings should be directed towards the antenna fields (yielding the shortest cable length). The general site reference drawing in annex 5.1 gives an example lay-out. |
| 6. | The position and orientation of the 96 LBA should be determined and marked on the LBA field by means of small poles with an accuracy of 1 degree from the specified coordinates as indicated on the site specific drawings (when available). 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 with an accuracy of 1 degree from the specified coordinates as indicated on the site specific drawings (when available). The HBA tile orientation should be determined with an accuracy of better than 1 degree. |
| 8. | The LB antennas must be installed in accordance with the procedure provided as a separate document (see RD.8).<br><br>Note: A plastic foil of 3 x 3 m is placed under the metallic groundplane 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 it can be considered to omit the foil. |
| 9. | The HBA tiles must be installed either in accordance with the procedure provided as a separate document (see RD.9) or will be placed on the site by the HBA supplier (TBD). |
| 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 grounded as explained in section 0. |
| 14. | After installation of all LBA the exact antenna positions (of the LNA head) should be measured with an accuracy of ± 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 + 1 cm which will form the new reference set of antenna coordinates for astronomical observations |

## 4.3 Infrastructure

This chapter describes the 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.

| | |
|---|---|
| 1. | The site should be provided with at least the following infrastructure:<br>- main power<br>- data connection |

### 4.3.1 Power infrastructure

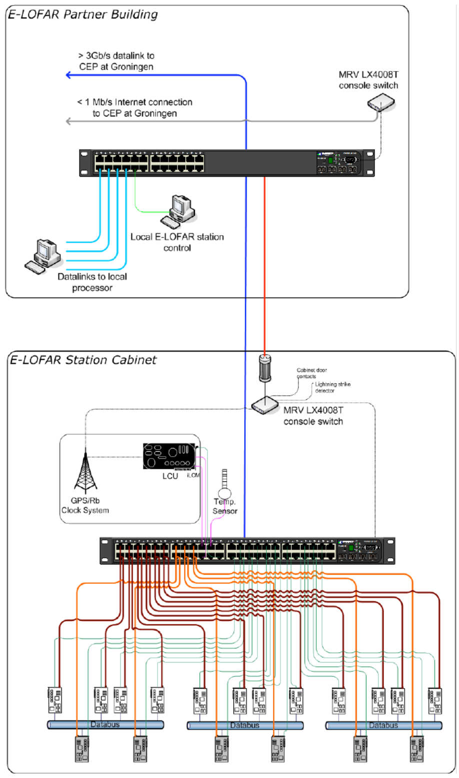
| | |
|---|---|
| 1. | The mains power cable should be routed in to the container via the pipes in the foundation |
| 2. | The mains power is a 3 phase mains 230/400 V connection with a minimum of 25 A per phase. |
| 3. | The main fuses of the station are located in the container and have a value of 32 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 rules) |

### 4.3.2 Data transport infrastructure

#### 4.3.2.1 Station Network Design

The data network of an E-LOFAR station contains two switches. Switch1, a Foundry FastIron LS 648, is located inside the E-LOFAR cabinet. Switch2 is located at the E-LOFAR Partner institute. Switch1 is used as the communication node of the E-LOFAR station. It handles all internal traffic and aggregates all in and outgoing traffic of the station into a single 10GbE link. Via this link a connection is realized to Switch2, a Foundry FastIron LS 624. With the use of Switch2 the two operation modes of the E-LOFAR station are realised: in operational mode 1 all the RSP-board observation data that is produced by the E-LOFAR station is sent to the central processor at Groningen. In operational mode 2 this observation data is made available to the E-LOFAR partner by connecting the RSP-board VLAN to the E-LOFAR partner ports of Switch2. In this latter mode the E-LOFAR station acts as a stand alone station, whose data is available for the local E-LOFAR partner, via four GbE links, These four 1GbE links are accessible via four 1000BASE-T ports.
In addition to the data connection, the E-LOFAR partner can also connect to the Local Control Unit (LCU) at the E-LOFAR station via its E-LOFAR partner ports. For this LCU link a local LCU VLAN is available.

To be capable of sending the data to the central processor, a 10GbE port of Switch2 must be connected to a 10GbE port of a dedicated link which connects a Switch2 10GbE port directly to CEP at Groningen. The dedicated link, which must have a bandwidth of at least 3 Gb/s, needs to be installed and maintained by the E-LOFAR partner. The optical 10GbE port of Switch2, with which the connection to the link to Groningen is realized, will be equipped with a 10GBASE-LX XFP. Since the entire LOFAR data transport network is based on 10 Gb/s technology, the use of 10 Gb/s lightpath technology for the link to Groningen is preferred.




In addition to the 10GbE data link between the two switches, a second link is present. This link connects a console switch at the E-LOFAR station to Switch2 via a media converter and a 100BASE-FX link. This network management link will be aggregated into the 10GbE link by Switch2, such that a connection to the network management system at Groningen is realized. Switch2 will be managed via a console switch at the partner building. For realizing a connection between this switch and CEP at Groningen a <1 Mb/s Internet connection needs to be available. At the console switch a RJ-45 10/100Base-T port is available for realising this connection.

The communication equipment that will be delivered as part of the E-LOFAR station is summarized in Section 2.2. These items will be configured, controlled and maintained by ASTRON-LOFAR, with support of the E-LOFAR partner. The fiber-optic cable (and its terminations) between the E-LOFAR cabinet and the E-LOFAR partner building, that is used for connecting both E-LOFAR switches, must be designed, deployed and maintained by the E-LOFAR partner. This will be done in such a way that the mentioned 10GBASE-LX and 100BASE-FX based links will function according to their specifications.

#### 4.3.2.2 Requirements for the fiber link between station and partner building

In this subsection the requirements for the two fiber pairs between the E-LOFAR cabinet and the patch panel at the Switch 2 location is given. The detail level in this specification is such that it can be used in the negotiations with the company that will deploy the cable. The given specification holds for a distance of less than 10km. In case a larger distance needs to be bridged, an adjusted specification and component list is needed, which also will be provided by ASTRON-LOFAR.

*Requirements for the fiber cable*

- The fibers in the cable must be of type G652-C or G652-D (IEC60793-2-50 B 1.3).
- The optical properties of the fibers must be according to the current common quality levels, both per kilometer as over its entire length.
- The optical loss of every fiber between the E-LOFAR station and the patchpanel at Switch2 must be below 4 dB in the wavelength window between 1310 nm and 1625 nm. This loss is measured between the adapters on the patchpanel at the E-LOFAR station and the patchpanel at the Switch2 location.
- The absolute chromatic dispersion in the O-band (1260 nm – 1360 nm) is less than 3,5 ps/nm.km.
- The chromatic dispersion in the C-band (1530 nm – 1565 nm) is less than 18 ps/nm.km.
- Low PMD levels (less than 0,5 ps/√km) are preferred.

*Requirements for the patchpanel adapters and connectors*

- The fibers between the E-LFOAR cabinet and the Switch2 location will be terminated on patchpanels with SC/PC adapters.
- The adapters and connectors in the link between the E-LOFAR cabinet and the Switch2 location must have a reflection level below -30 dB and must be specified for a optical loss of less than 0.5 dB.

*Requirements for the splices*

- Only fusion splices must be used. Glued or mechanical splices are not allowed.
- The maximum allowed optical loss over a single splice is 0.5 dB
- The average loss per splice must be less than 0.10 dB.

#### 4.3.2.3 E-LOFAR station network components

The following items are part of the E-LOFAR station hardware:

- 1 x Foundry FastIron LS 648
- 1 x Foundry FastIron LS 624
- 3 x 10GBASE-LX XFPs
- 1 x 100BASE-FX SFP
- 2 x MRV Console Server
- 1 x MRV 10/100BaseTX to 100BASE-FX converter (SM, 1310nm, 0-35km, DSC)

#### 4.3.2.4 Requirements for the link between the partner site and the central processor

For connecting the E-LOFAR station to the Central Processor (CEP) at Groningen, the E-LOFAR partner needs to provide a communication link with a 10GbE interface at both sides. This link has to transfer the data traffic to and from Switch2 with a bandwidth (per direction) of at least 3 Gb/s. This communication link will hold a number of data streams which are virtually separated with the use of VLANs. The E-LOFAR connection link must be a layer 2 link that supports:

- At least 3 Gb/s of bandwidth
- 10GbE interfaces at both sides
- 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

The E-LOFAR connection to CEP must be a dedicated link which transfers its data separated from the Internet. The most suitable technology for this is 10 Gb/s lightpath technology that is a.o. supplied by many ISPs. The link has to comply with a number of availability, maintenance and security requirements which are described in Section 4.3.2.5 and 4.3.2.6.

#### 4.3.2.5 Requirements for the partner systems

In addition to the E-LOFAR communication hardware mentioned in Section 2.2, the following items are needed for the E-LOFAR communication link:

- a fiber-optic cable between the E-LOFAR cabinet and the Switch2 location
- a communication link with a minimum bandwidth of 3 Gb/s, which connects a 10GBASE- LX port on the E-LOFAR routing switch to a 10GBASE- LX port on the lightpath switch at the central processor site at Groningen.
- a <1Mb/s Internet connection

All three items need to be provided by the E-LOFAR partner. Below, a number of requirements for the construction, availability, maintenance and security of this cable / link are given which have to be followed up by the E-LOFAR partner for a flawless operation.

| | |
| --- | --- |
| 1. | The fiber-optic cable between Switch1 and Switch2 must be terminated at both sides on a patch panel with SC/PC patch positions. |
| 2. | This fiber-optic cable and its terminations are configured, constructed and maintained in such a way that the Switch1 and Switch2 can realize a 10GbE connection via that cable. |
| 3. | The data connection between Switch2 and the lightpath/CEP switch should 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 Switch2 and the lightpath/CEP switch may not alter the data packets as they are sent out by the E-LOFAR routing switch |
| 5. | Small amounts of packet loss (<10 packets/s per station) in the data connection between Switch1 and the lightpath/CEP switch are only acceptable when ASTRON/LOFAR has concluded that the packet loss is not causing any LOFAR system problems. |
| 6. | A high level of packet loss (>10 packets/s per station) in the data connection between Switch2 and the lightpath/CEP switch is not acceptable |
| 7. | The data link between Switch2 and the lightpath/CEP switch may not have a delay larger than 100 ms. |
| 8. | The 10GbE stream from a E-LOFAR station contains the following sub-streams:<br>a. Observation with required bandwidth: 2.2 Gb/s<br>b. Monitoring and Control with required bandwidth of 100 Mb/s<br>c. Network control with required bandwidth of 10 Mb/s<br>d. Transient Mode with a varying required bandwidth which is in the order of several Gb/s<br><br>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 E-LOFAR partner. |
| 9. | Any maintenance to the fiber-optic cable between the Switch1 and Switch2 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 Switch2 and the lightpath/CEP 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 Switch1 and Switch2, a report must be created by the E-LOFAR partner. This report contains an incident and a repair plan which will be provided to ASTRON/LOFAR preferably 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 Switch1 and Switch2 will be configured and maintained by ASTRON / LOFAR. The local E-LOFAR partner organization supplies assistance in this configuration and maintenance task. |
| 13. | In case of failure of the active equipment and/or failure in the fiber-optic infrastructure in the link between Switch2 and the lightpath/CEP switch, an incident and repair plan must be made by the E-LOFAR partner. This incident and a repair plan is to 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. If an E-LOFAR partner needs more time for providing the incident and |

| | |
|---|---|
| | repair plan to ASTRON/LOFAR, the E-LOFAR partner and LOFAR/ASTRON will agree on an adjusted time. In case the problem exists for several days, ASTRON/LOFAR will be informed daily on the status of the repair. |

#### 4.3.2.6 Security and availability related items

The E-LOFAR partner 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 that originate from the partner's data link, it will be disconnected from the LOFAR systems. In order to prevent such a situation the following preventive measures are strongly recommended to be taken by the partner:

| | |
|---|---|
| 1. | In case an intrusion is detected in the active equipment that is placed in the link between Switch2 and the lightpath/CEP interface switch, this should be directly (within 1 hour) reported to ASTRON / LOFAR (LOFAR control room) |
| 2. | In case a connection between an E-LOFAR station and the lightpath/CEP 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 E-LOFAR partner has shown that the mentioned issues are removed / not present the link will be restored. |
| 3. | An E-LOFAR partner has the responsibility to provide a secure link.<br><br>N.B.: The security of the link will be assessed based on information provided by the E-LOFAR partner regarding the link between the E-LOFAR station and the lightpath/CEP switch at Groningen. |
| 4. | An E-LOFAR partner has the responsibility to provide a qualitative good link with proper availability. |
| 5. | Before the link between an E-LOFAR station and the lightpath/CEP switch at Groningen is connected to the LOFAR systems at Groningen, the involved E-LOFAR partner has to supply a report in which the construction and configuration of the link between Switch2 and Groningen is described. ASTRON / LOFAR will assess with the E-LOFAR partner the quality of the link. |
| 6. | In case an E-LOFAR partner wants to connect his local data processor systems to the Internet and /or other, non-LOFAR networks, the partner has to install a proper firewall and intrusion detection system between the local data processor system and the Internet /non-LOFAR networks. |

**Fire prevention:**
The container does not contain any means to prevent fire or to extinguish fire. However, temperatures are measured at several places and 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.

## 4.4 Resources and logistics

In order to achieve an efficient installation of a LOFAR station on the desired location, the customer will be asked carry out some work and to support LOFAR/ASTRON during the preparation and installation periods. This chapter discusses the resources expected to be provided by or via the customer during preparation and installation of the LOFAR station.

Measurement of antenna positions etc. is usually performed best by local specialized companies.
A reference schedule will provide the logic and expected throughput times during the preparation and installation period, see annex 5.3. LOFAR/ASTRON personnel will arrive and carry on with the electronics installation when the preparation of the site has been finished.

To familiarize with preparations and equipment it is suggested that the customer sends a representative to LOFAR/ASTRON in order to get hands-on experience.

The table below details the expected support:

| | |
|---|---|
| 1. | The customer should provide all necessary resources during the site preparation period as indicated in the previous sections of this chapter (LOFAR/ASTRON personnel will be available for consultancy if necessary on-site) |
| 2. | The customer will agree a schedule and workflow as e.g. shown in annex 5.3 with LOFAR/ASTRON. |
| 3. | The customer should provide at least the following personnel and equipment to carry out the jobs mentioned in sections 4.1, 4.2, 4.3 and 0:<br>a. For installation of LBA groundplanes and antennas at least 2 persons<br>b. For installation of HBA tiles at least 2 persons and crane including driver.<br>c. For placement of the equipment container 2 persons and crane including driver. |
| 4. | The customer should make 2 persons available during the installation work by ASTRON/LOFAR to support the ASTRON personnel. *)<br><br>*) For an efficient electronics installation, the customer should provide sufficiently skilled resources to support the LOFAR/ASTRON personnel (e.g. people with hands on-experience as suggested above). |
| 5. | For preparation of the site, leveling, stabilizing and digging, casting of the concrete cabinet foundation etc, adequate equipment and personnel should be available to perform this job in line with the preparation schedule of annex 5.4. |
| 6. | Near the container, on the site, a (temporary) shelter for personnel and for temporary storage of equipment should be available in order to allow for an efficient electronics installation in the container. |
| 7. | In case no equipment storage near the container is possible, it may be an option that customer personnel brings the equipment as requested by the ASTRON/LOFAR personnel. |
| 8. | Near or on the site a toilet should be available. |
| 9. | The customer should arrange for catering on site while ASTRON/LOFAR personnel are present and in case there are no nearby facilities. |

## 4.5 Deliverable items list

The table below specifies the hardware that will be furnished by ASTRON/LOFAR during the preparation work supported by the customer.

| Item | Number | Remark |
|---|---|---|
| LBA LNAs, including springs and cords. | 96 | |
| LBA poles/pegs | 96 sets | |
| LBA ground plane foil | 96 | |
| Container with RF-tight compartment | 1 | |
| HBA tiles | 96 | |
| LBA Coax cables | 192 | Different sizes |
| HBA Coax cables | 192 | Different sizes |

**Table 4.5-1 Hardware delivered by ASTRON/LOFAR**

In the table below the hardware is listed that is expected to be delivered or provided locally by the customer mainly because of practical reasons:

| Item | Number | Remark |
|---|---|---|
| LBA ground plane mesh | 96 | Specification Annex 5.3 |
| Cable feed through pipes | 6 sets | |
| Splice box including optical modules | 1 | |
| Concrete structure for the RF-tight container | 1 | Specification Annex 5.2 |
| Power connection | 1 | |
| Data connection | 1 | |

**Table 4.5-2 Hardware delivered by the customer**

# 5 Annexes

## 5.1 Annex 1 Reference site layout (examples)

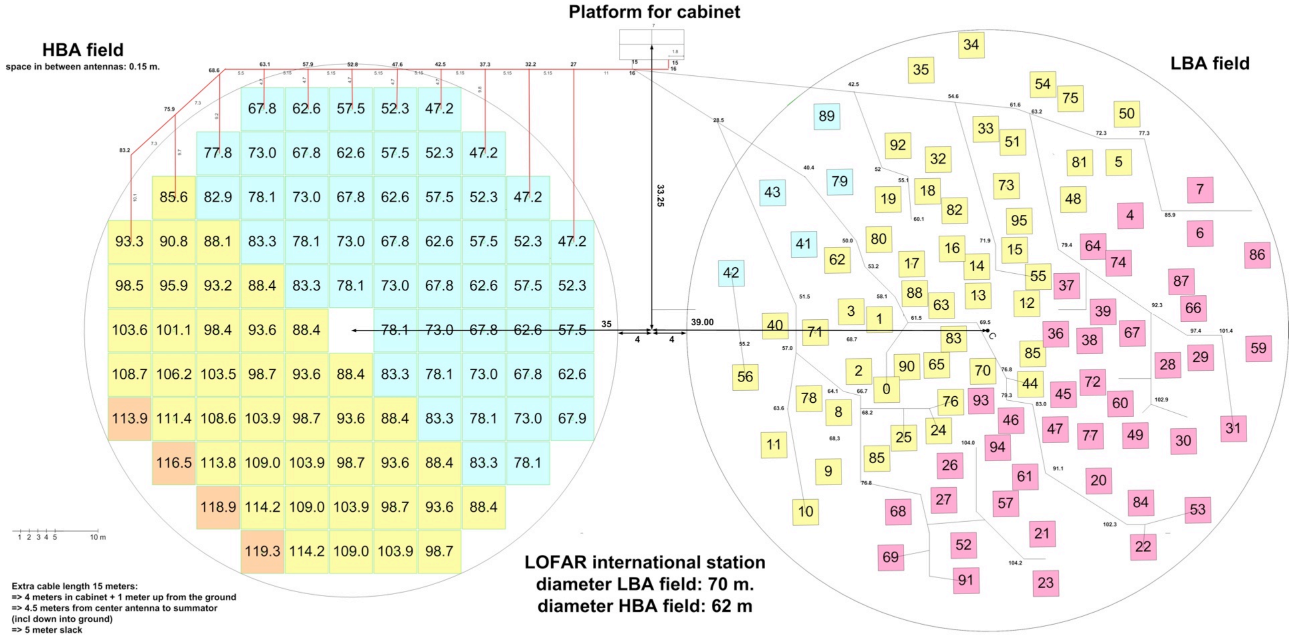
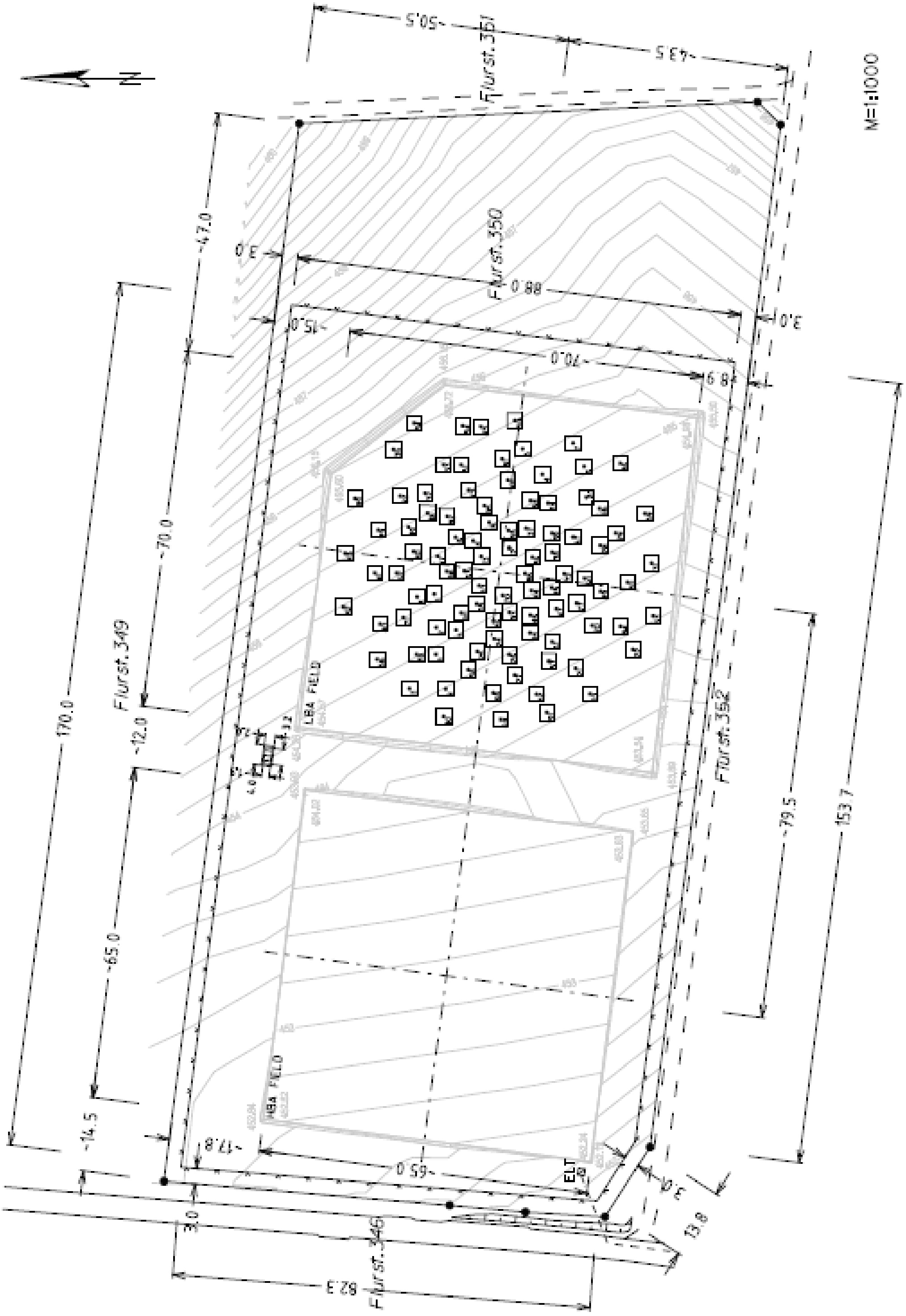
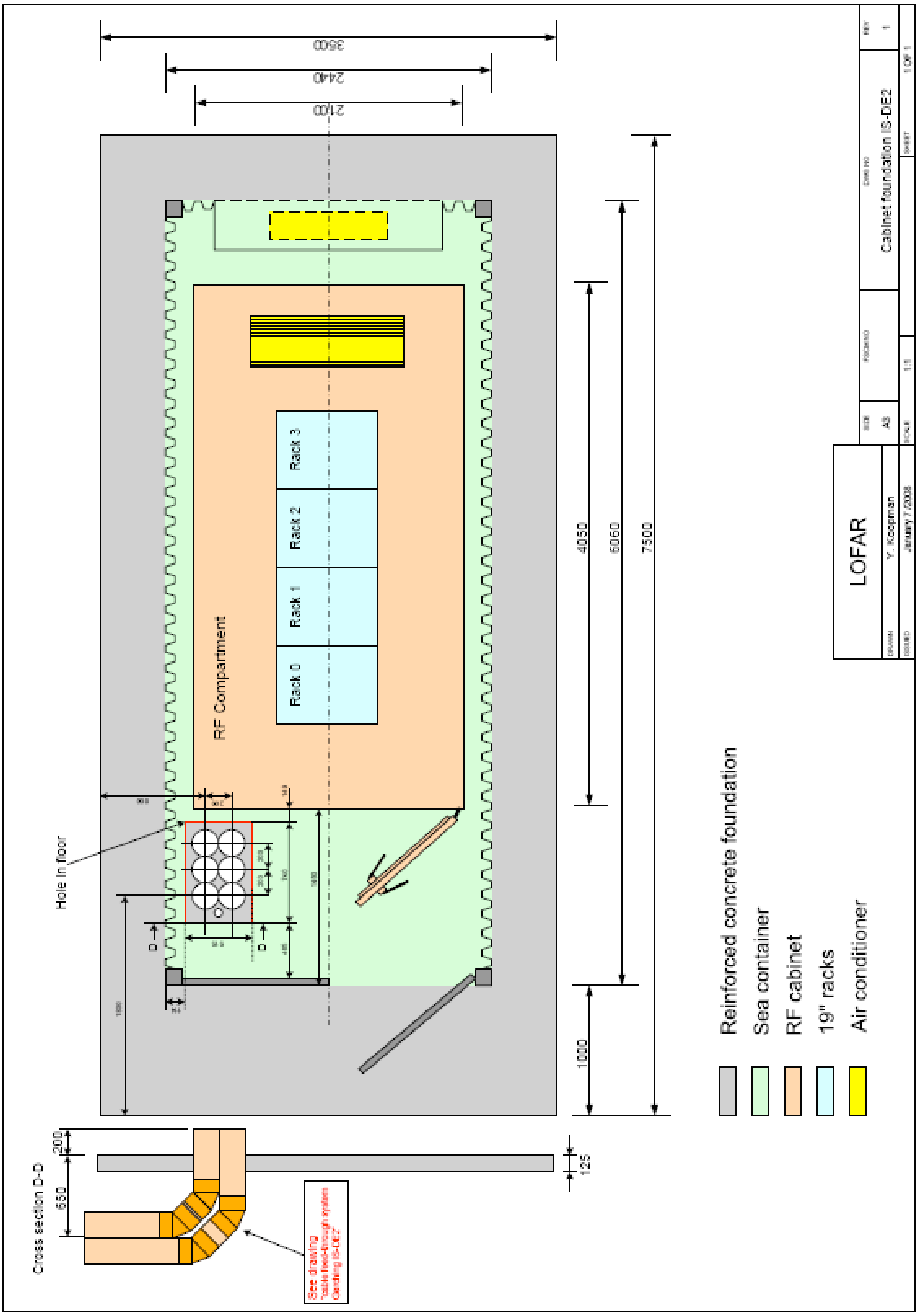



**Figure 5-1 Reference site layout**

**Figure 5-2 Example LBA layout Garching**



## 5.2 Annex 2 Container foundation drawing



<u>The Placement of the concrete foundation</u>:

Before the foundation can be cast, the six plastic tubes (see figures below) have to be placed first in the correct position underneath the place where the foundation will be. The tubes should stick out 20cm above the foundation (as indicated in the drawing). The thickness of the foundation (suggested in the drawing to be 12.5cm) is only a suggestion and needs to be determined dependent on the local ground properties.

The small hole in the drawing represents the entrance for power (3 phases) and the fibre cables, which also have to be in place before the foundation for the container is cast. Actually, there should be two holes in the drawing representing two plastic tubes that are sufficient to encompass the power and fibre cable that should be placed before the foundation is cast.

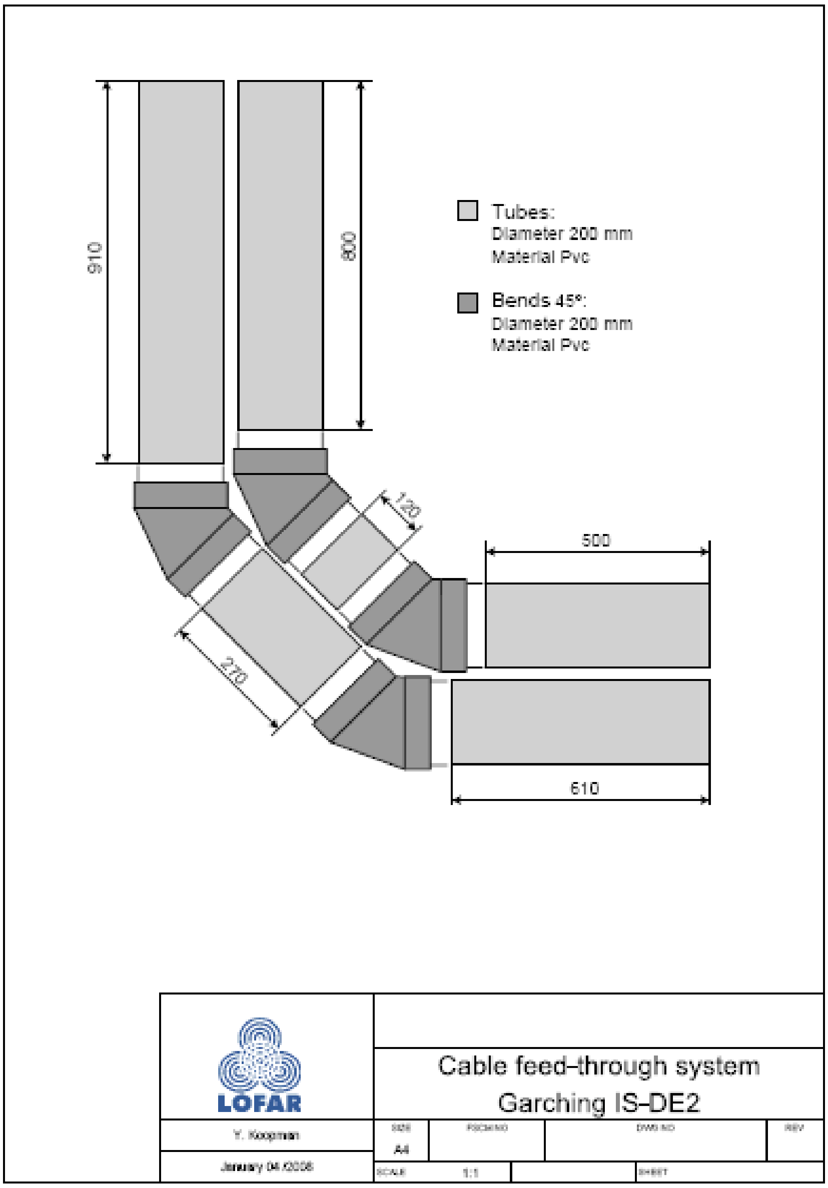


**Figure 5.2-1: Example of the plastic tubes for the antenna cables as defined in the drawing above.**

## 5.3 Annex 3 Ground plane

Main function of the antenna ground plane is to increase the receiving capability of the Low Band dipole antenna. Secondary function of the ground plane is to block the vegetation growth below the antenna

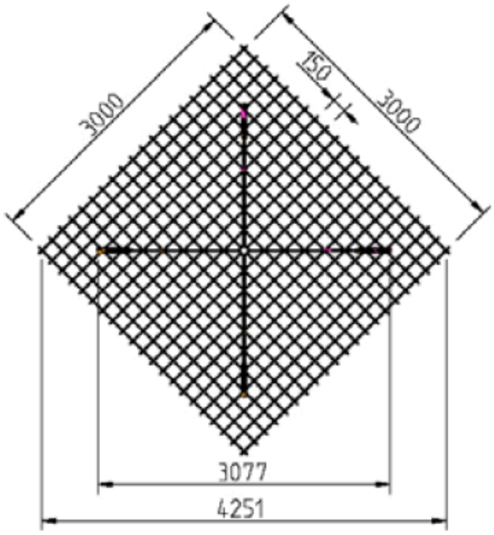



**Figure 5-3: Ground plane with foil. Left: photo. Right: specifications.**

The ground plane is build out of a concrete reinforcement metal mesh that could be nickel-plated to lower the corrosion rates so that a lifetime up to 25 years becomes feasible. Dimensions of the ground plane are 3x3 meters with a mesh width of 15 cm and a mesh diameter of 5 mm. The ground plane exceeds the base of the antenna with 60 cm at each side so that mowing close to the antenna is not necessary. The vegetation blocking function is realised by placing a foil below the metal ground plane.

Ground plane specification:

- Lifetime ground plane inclusive foil 15 years
- Dimensions: area 3x3 meter; mesh width 15 cm; mesh thickness so that a lifetime of 15 years is realised. Specification and tolerances see Figure 5-4.
- Block vegetation growth under whole 3x3 meter ground-plane
- All meshes should be galvanic connected with one-another

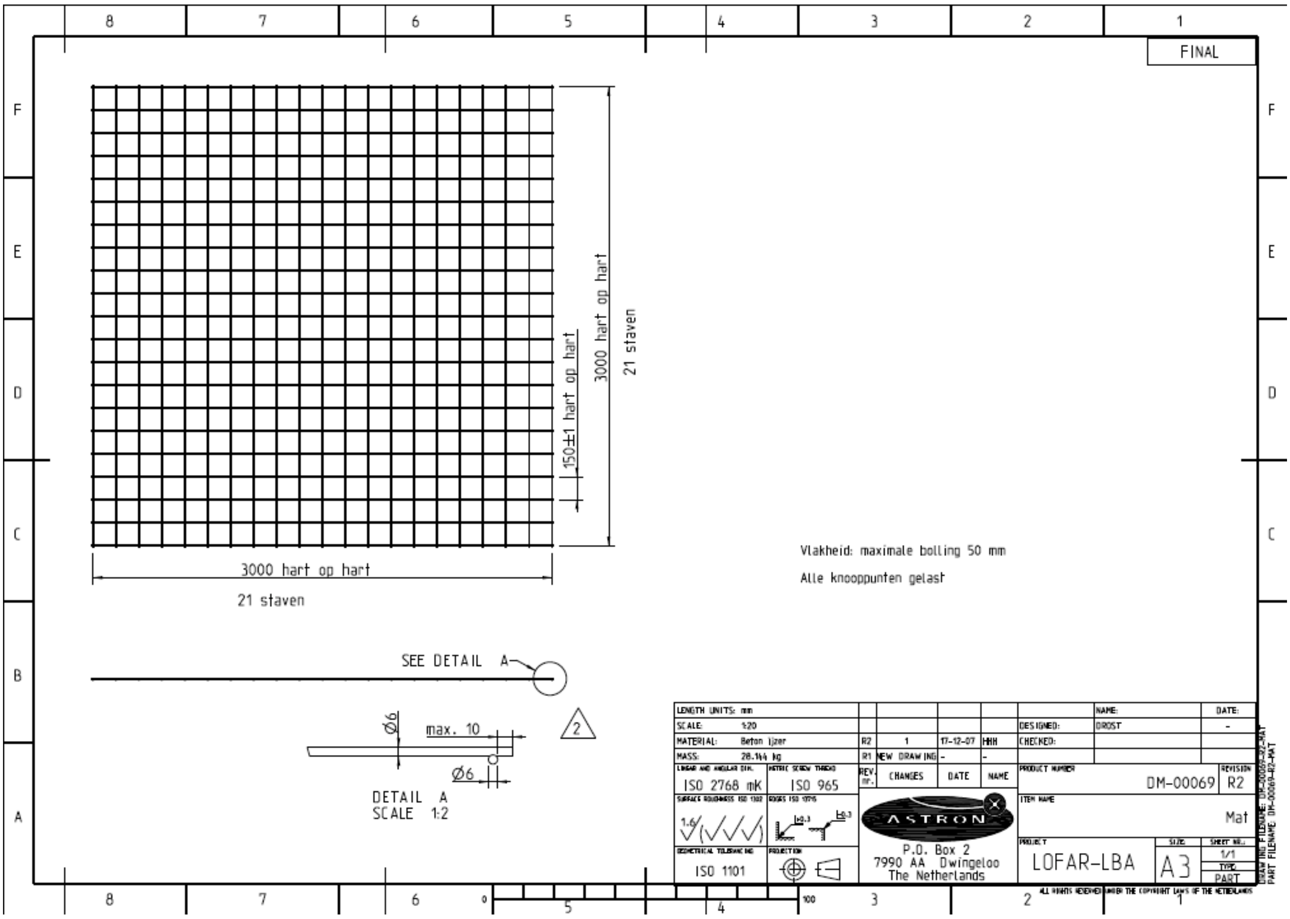
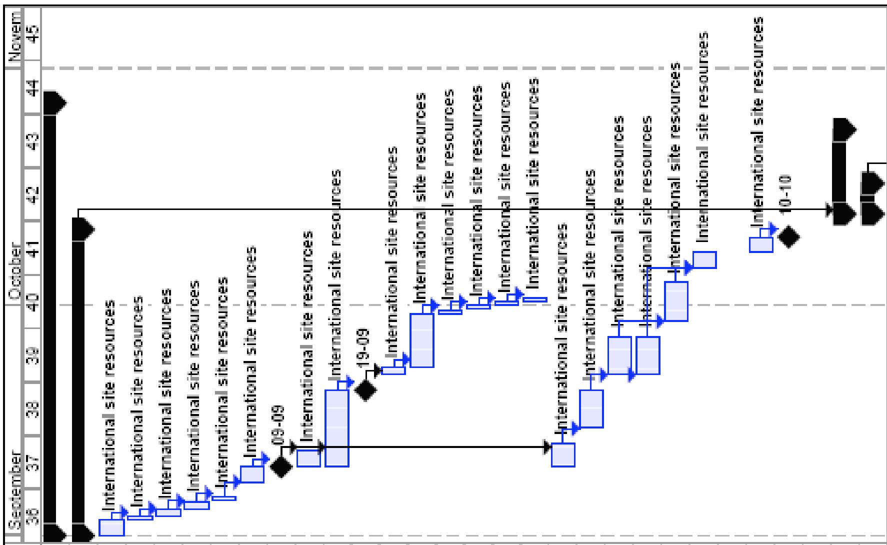



**Figure 5-4: Specification of the LBA ground plane mesh and its tolerances.**

## 5.4 Annex 4 Reference schedule for preparations

| ID | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|
| 1 | **International station preparation and installation** | **40.5 d** | **Mon 01-09-08** | **Mon 27-10-08** | |
| 2 | **Site preparations** | **30 d** | **Mon 01-09-08** | **Fri 10-10-08** | |
| 3 | Determine position LBA, HBA field and container | 2 d | Mon 01-09-08 | Tue 02-09-08 | |
| 4 | Temporary access roads (if required) | 0.5 d | Wed 03-09-08 | Wed 03-09-08 | 3 |
| 5 | Remove growth (if required) | 1 d | Wed 03-09-08 | Thu 04-09-08 | 4 |
| 6 | Fill in sand for container & dirt or sand for antenna fields | 1 d | Thu 04-09-08 | Fri 05-09-08 | 5 |
| 7 | Placing of mobile canteen & toilet | 0.5 d | Fri 05-09-08 | Fri 05-09-08 | 6 |
| 8 | Levelling of LBA and HBA sections | 2 d | Mon 08-09-08 | Tue 09-09-08 | 7 |
| 9 | Inspection point (recommended) | 0 d | Tue 09-09-08 | Tue 09-09-08 | 8 |
| 10 | Grounding rods (reference, safety) | 2 d | Wed 10-09-08 | Thu 11-09-08 | 9 |
| 11 | Preparation of container foundation incl. cable feedthrough pip | 8 d | Wed 10-09-08 | Fri 19-09-08 | 9 |
| 12 | Inspection point (recommended) | 0 d | Fri 19-09-08 | Fri 19-09-08 | 11 |
| 13 | Foundation placement (concrete casting) | 1 d | Mon 22-09-08 | Mon 22-09-08 | 12 |
| 14 | Concrete setting time (minimum 1 week) | 5 d | Tue 23-09-08 | Mon 29-09-08 | 13 |
| 15 | Container placement | 0.5 d | Tue 30-09-08 | Tue 30-09-08 | 14 |
| 16 | Installation of optical splice box and modules | 0.5 d | Tue 30-09-08 | Tue 30-09-08 | 15 |
| 17 | Data connection last mile deployment and connection | 0.5 d | Wed 01-10-08 | Wed 01-10-08 | 16 |
| 18 | Power last mile deployment and connection | 0.5 d | Wed 01-10-08 | Wed 01-10-08 | 17 |
| 19 | LBA/HBA position measurements/marking | 3 d | Wed 10-09-08 | Fri 12-09-08 | 9 |
| 20 | LBA Coax routing & digging | 5 d | Mon 15-09-08 | Fri 19-09-08 | 19 |
| 21 | HBA Coax routing & digging | 5 d | Mon 22-09-08 | Fri 26-09-08 | 20 |
| 22 | LBA assembly, placement & connection | 5 d | Mon 22-09-08 | Fri 26-09-08 | 20 |
| 23 | HBA assembly, placement & connection | 5 d | Mon 29-09-08 | Fri 03-10-08 | 21 |
| 24 | Connect coax cables to RF panel interface | 2 d | Mon 06-10-08 | Tue 07-10-08 | 22,23 |
| 25 | Final access road (if required) | 0 d | Tue 07-10-08 | Tue 07-10-08 | 24 |
| 26 | Sowing of grass (if required) | 2 d | Wed 08-10-08 | Thu 09-10-08 | 25 |
| 27 | Final inspection site preparations (mandatory) | 1 d | Fri 10-10-08 | Fri 10-10-08 | 26 |
| 28 | Contingency (weather, problems) | 0 d | Fri 10-10-08 | Fri 10-10-08 | 27 |
| 29 | **Station Integration and Test** | **9 d** | **Mon 13-10-08** | **Thu 23-10-08** | 2 |
| 30 | Container equipment Integration | 4 d | Mon 13-10-08 | Thu 16-10-08 | |

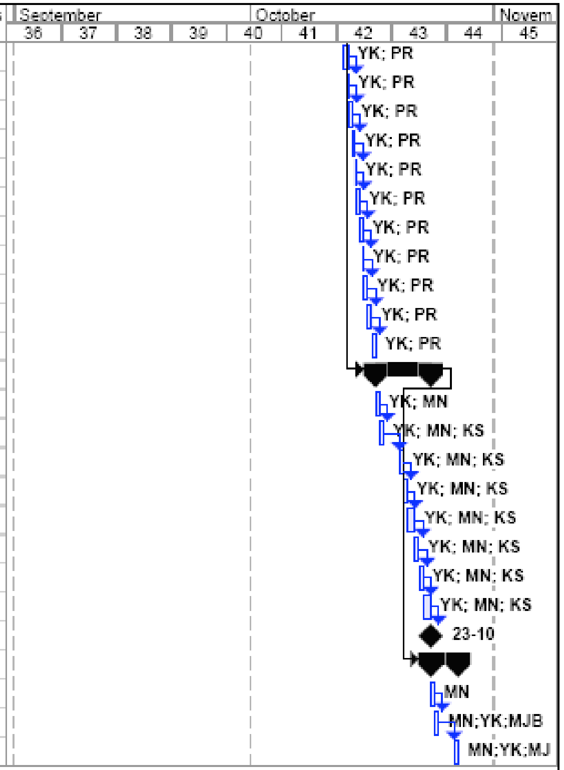



Project: RO-sched station preps intern
Date: Mon 04-02-08

| | | | | | |
|---|---|---|---|---|---|
| Task | | Milestone | | External Tasks | |
| Split | | Summary | | External Milestone | |
| Progress | | Project Summary | | Deadline | |

Page 1

| ID | Task Name | Duration | Start | Finish | Predeces |
|---|---|---|---|---|---|
| 31 | Mounting of subracks | 0.5 d | Mon 13-10-08 | Mon 13-10-08 | |
| 32 | Line filters and distribution etc. | 0.25 d | Mon 13-10-08 | Mon 13-10-08 | 31 |
| 33 | Install Power connections & first switch-on | 0.25 d | Mon 13-10-08 | Mon 13-10-08 | 32 |
| 34 | Power supplies | 0.25 d | Tue 14-10-08 | Tue 14-10-08 | 33 |
| 35 | LCU installation | 0.25 d | Tue 14-10-08 | Tue 14-10-08 | 34 |
| 36 | Network equipment installation & check | 0.5 d | Tue 14-10-08 | Tue 14-10-08 | 35 |
| 37 | GPS receiver and antenna installation | 0.25 d | Wed 15-10-08 | Wed 15-10-08 | 36 |
| 38 | Rubidium clock unit installation | 0.25 d | Wed 15-10-08 | Wed 15-10-08 | 37 |
| 39 | Cables from RF interface panel to RCU's | 0.5 d | Wed 15-10-08 | Wed 15-10-08 | 38 |
| 40 | Internal cabling/connections | 0.5 d | Thu 16-10-08 | Thu 16-10-08 | 39 |
| 41 | Miscellaneous items and material (temp sensors) | 0.5 d | Thu 16-10-08 | Thu 16-10-08 | 40 |
| 42 | **I/F check & Testing station 1** | **5 d** | **Fri 17-10-08** | **Thu 23-10-08** | **30** |
| 43 | Basic checks with BITE, test SW, test set | 0.5 d | Fri 17-10-08 | Fri 17-10-08 | |
| 44 | Start up & test WAN | 0.5 d | Fri 17-10-08 | Fri 17-10-08 | 43 |
| 45 | MAC Local check-out | 0.5 d | Mon 20-10-08 | Mon 20-10-08 | 44 |
| 46 | Receiver chain test | 0.5 d | Mon 20-10-08 | Mon 20-10-08 | 45 |
| 47 | Operational tests (mem-179 Eng test plan) | 1 d | Tue 21-10-08 | Tue 21-10-08 | 46 |
| 48 | beamformer tests | 0.5 d | Wed 22-10-08 | Wed 22-10-08 | 47 |
| 49 | Station-Central systems tests | 0.5 d | Wed 22-10-08 | Wed 22-10-08 | 48 |
| 50 | Preparation for acceptance/handover | 1 d | Thu 23-10-08 | Thu 23-10-08 | 49 |
| 51 | Contingency (weather, problems) | 0 d | Thu 23-10-08 | Thu 23-10-08 | 50 |
| 52 | **Station acceptance** | **1.5 d** | **Fri 24-10-08** | **Mon 27-10-08** | **42** |
| 53 | Demo test | 0.5 d | Fri 24-10-08 | Fri 24-10-08 | |
| 54 | Delivery review and DDP | 0.5 d | Fri 24-10-08 | Fri 24-10-08 | 53 |
| 55 | handover to customer | 0.5 d | Mon 27-10-08 | Mon 27-10-08 | 54 |




Project: RO-sched station preps intern
Date: Mon 04-02-08

| Task | | Milestone | | External Tasks | |
|---|---|---|---|---|---|
| Split | | Summary | | External Milestone | |
| Progress | | Project Summary | | Deadline | |

Page 2

## 5.5 Annex 5 LOFAR station building example

The following pages serve as an example regarding the construction of a LOFAR station in the Netherlands.

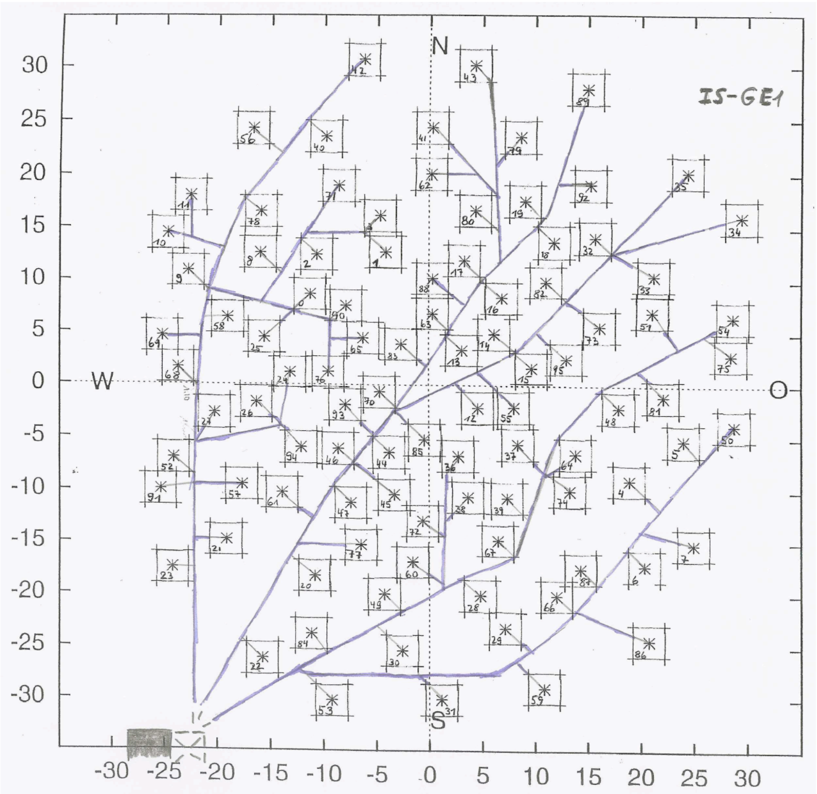
Note that the station electronics are mounted in cabinet as appropriate for the Dutch site conditions and not in the RF-tight compartment of a modified sea container that is proposed to be used for international sites.

**HOW TO BUILD A LOFAR STATION**

In this document a brief overview is given how a LOFAR station is build up. This can be seen as an impression how to build a LOFAR station.

Configuration

In the Figure below the configuration of the Low Band Antennas is shown for international stations. The distance between the antennas is not the same. This configuration of the 96 antennas must be rotated with an angle which will be delivered at the time of installation.




The scale is in meters.

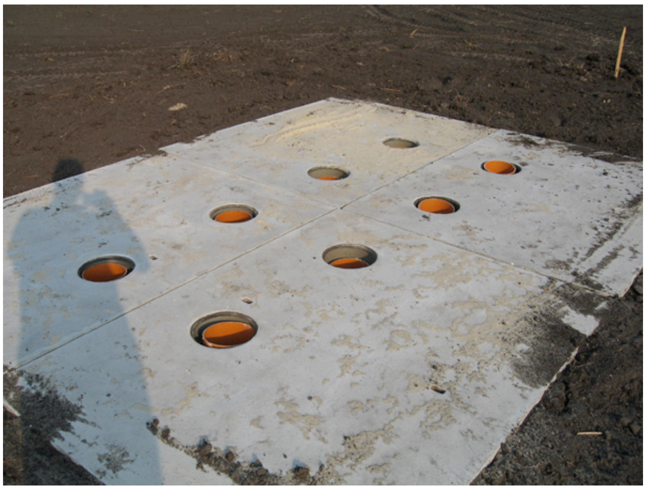
The position accuracy is plus or minus 6 cm for the LBA field (see section 2.1.3). After placement of the antennas, all the positions must be measured (again) with an accuracy of 1 cm. These numbers will be fed into the station software.

All the 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 cables 192. The cables are placed in trenches of approximately 60 cm deep (see also section 2.1.3. for specifications)

Placement of the antennas.

The first thing to do at the field is flattening the ground. It is allowed to place the whole field under a certain angle (as long as the angle is known).

The next step is the construction of a concrete construction with 8 tubes into the ground. In these tubes the cables will be fed from under the ground towards the cabinet. Be aware that this is an image of the stations in the Netherlands using the standard LOFAR cabinet. For international stations a different cabinet is used with different requirements for the tubes in the concrete construction.



After the construction of the concrete platform the cabinet can be placed on this construction.

The cabinet consists of 4 compartments. The first three are used for the receiver units and the digital processing. The fourth compartment is for control, power connections, rubidium clock, local control unit etc.

The next thing to do is placing the antennas one by one:

ASTRON

Step 1


After all the positions were measured (by a geodetic company) and marked with a small wooden stick. A small crane created a trench for the 2 coax cables for the antenna.

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 exactly in the wind directions. This can easily been done because a second maker (wooden stick) is made exactly towards the north.

* The foil is placed under the metallic groundplane 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 the foil can be omitted.

Step 4

The groundplane is placed, also exactly in the wind directions. The groundplane is part of the antenna and will create a bundle towards the sky. This groundplane is “normal” construction steel (for concrete constructions) with the exception that all the crossings of the wires are welded (this is not normal for this material).

Step 5

The 2 coax cables are fed into a prepared tube of exactly 1.7 meters.

<u>Step 6</u>


The antenna is connected with the two coax cables. There is a hole in the antenna such that the tube perfectly fits in the potted LBA.

<u>Step 7</u>

The tube has little slots in the bottom which make a perfect fit on the grid of the wire mess. The two antenna cables have a little over length at the bottom, to assemble but also disassemble the antenna easily.

Step 8


Then the 4 tension cord/springs (2 arms of the antenna have tension cords, the other two springs) are connected by 4 ground pins.

And so …

The Low Band Antenna is ready.

You see two wraps of the cables. All the cables are labeled. The lowest number is connected to the X polarization of the antenna and the highest to the Y polarization.

The following step is to dig trenches and place the cables into it. No windings are allowed. An impression:

Finally the field looks like this:

## 5.6 Annex 6 Inspection checklist

This checklist will be used for the evaluation of the site preparations and will be added to the Minutes of Meeting (MoM) in which additional remarks and open work can be recorded. In case the outcome of the inspection is “less suitable” it means that the MoM will contain the actions to be taken in order to improve the situation.

The MoM agenda should consider the following items:

1. As-Built information/documentation
2. Site inspection results
3. Deviations and problems
4. Critical issues (including safety hazards)
5. Discussion of the Data Delivery Package (DDP)
6. Action items
7. Filling/signing and adding of Inspection check list

# 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 4.3? | ❑ | ❑ |
| 5. Are the Safety measures completed and agreed of section 0, including earthing resistance measurement report? | ❑ | ❑ |
| 6. Are problem reports and deviations available?(if applicable)? | ❑ | ❑ |
| 7. Are the antenna position measurement results available? | ❑ | ❑ |

The Station preparations at the location mentioned above are:

❑ Less suitable site for a LOFAR station if one or more items of above list indicate “No”. See the MoM for possible improvement activities and suggestions.

❑ Recommended to continue the station built up if all items indicate “Yes”

Signatures of:

Customer representative: LOFAR representative:

This sheet has to be added to the MoM written after the inspection