User Manual

RT-1000 Multichannel Recommendation for Site Selection and Antenna Installation

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Note

The manufacturer reserves the right to make modifications at any time and without previous information of the here described product.

Content

1 General Information

The operator of a direction finder (DF) is interested in knowing the exact direction towards an aircraft or maritime vessel. However, a direction finder is measuring the angle of incidence of a signal.
As long as the direction towards the aircraft or ship and the direction from which the signal arrives are identical, the DF operator will be satisfied.
If this is not the case, we are talking about bearing errors – which is not true! The direction finder is working without error, but the signal comes from a wrong direction.
Therefore, it is of highest importance that the site for the antenna installation is selected so that the radio wave from the target is reaching the direction finder antenna always on the direct path.
If the signal (or a part of the signal) arrives to the antenna via a reflector, the DF will show the direction to the reflector – and not to the aircraft (in ATC application) or, (in VTS applications), to the vessel. The controller will blame a malfunction, but it is just a difference of what he will expect to what he will get.
In practice, the main subjects which will influence the bearing results are those reflections.
Four main parameters are influencing the magnitude and direction of the failure caused by reflections:

- The position of the DF Antenna
- The position of the transmitter antenna
- The position of the Reflector
- The signal wave length.

Objects interacting with electromagnetic fields, such as metallic objects but also, for example, wet wood, may reflect the signals to be received by a direction finder. Additionally, such objects, placed in between transmitter antenna and DF antenna, might attenuate the directly received wave.
More generally, if the direct wave is much stronger than the reflected wave, the correct direction will be shown by the direction finder. If the direct wave is much weaker than the reflected wave, the Direction Finder will show the direction to the reflector. In most cases, the direct wave will be stronger than the reflected wave, but not much stronger – in such a case, the measured direction is an overlay of the direction of the transmitter and the direction of the reflection source.

A second problem can be the influence of interfering signals. The DF antenna will not only be reached by the signal of the aircraft or vessel, but also be reached by other signals on different frequencies. The signal of a nearby VOLMET, VOR or AIS transmitter will be much stronger than the signal of a distant aircraft or ship.
Those aspects will be handled later on in this document.

Caution

LED-based obstacle lights should not be used.

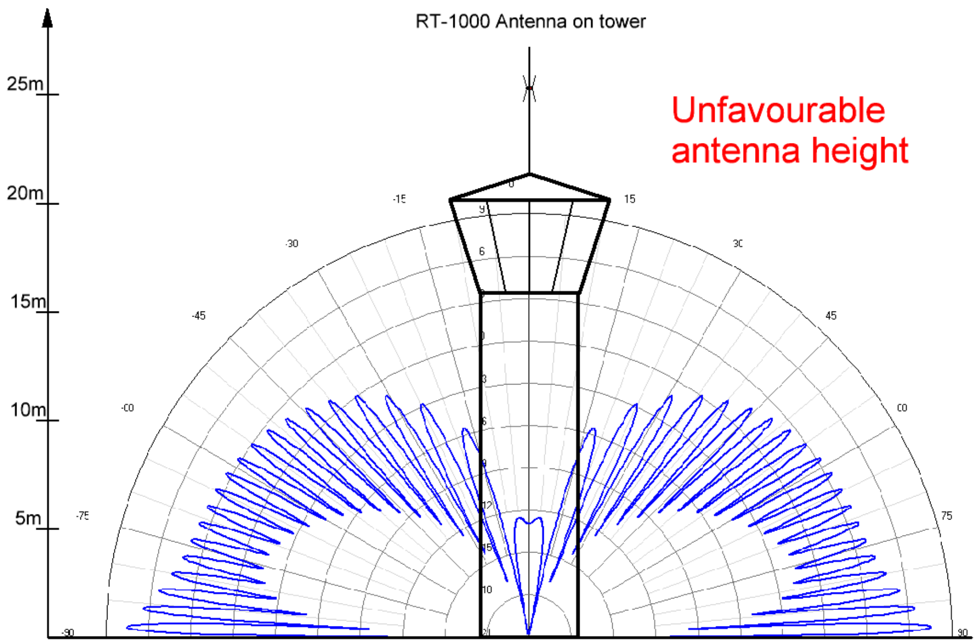
LED-based obstacle lights may disturb the reception of the DF system due to the integrated power supply.

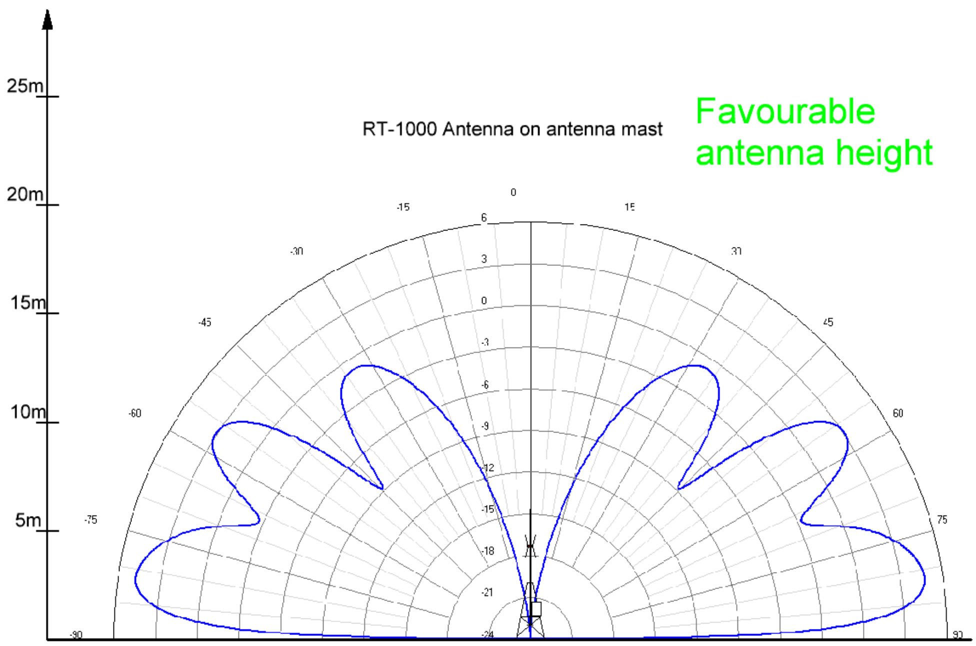
The use of the RHOTHETA obstacle light as defined in the options list will prevent such problems.

2 Recommendation for Air Traffic Control installations

2.1 Influence of the Vertical Antenna Pattern for tower installations

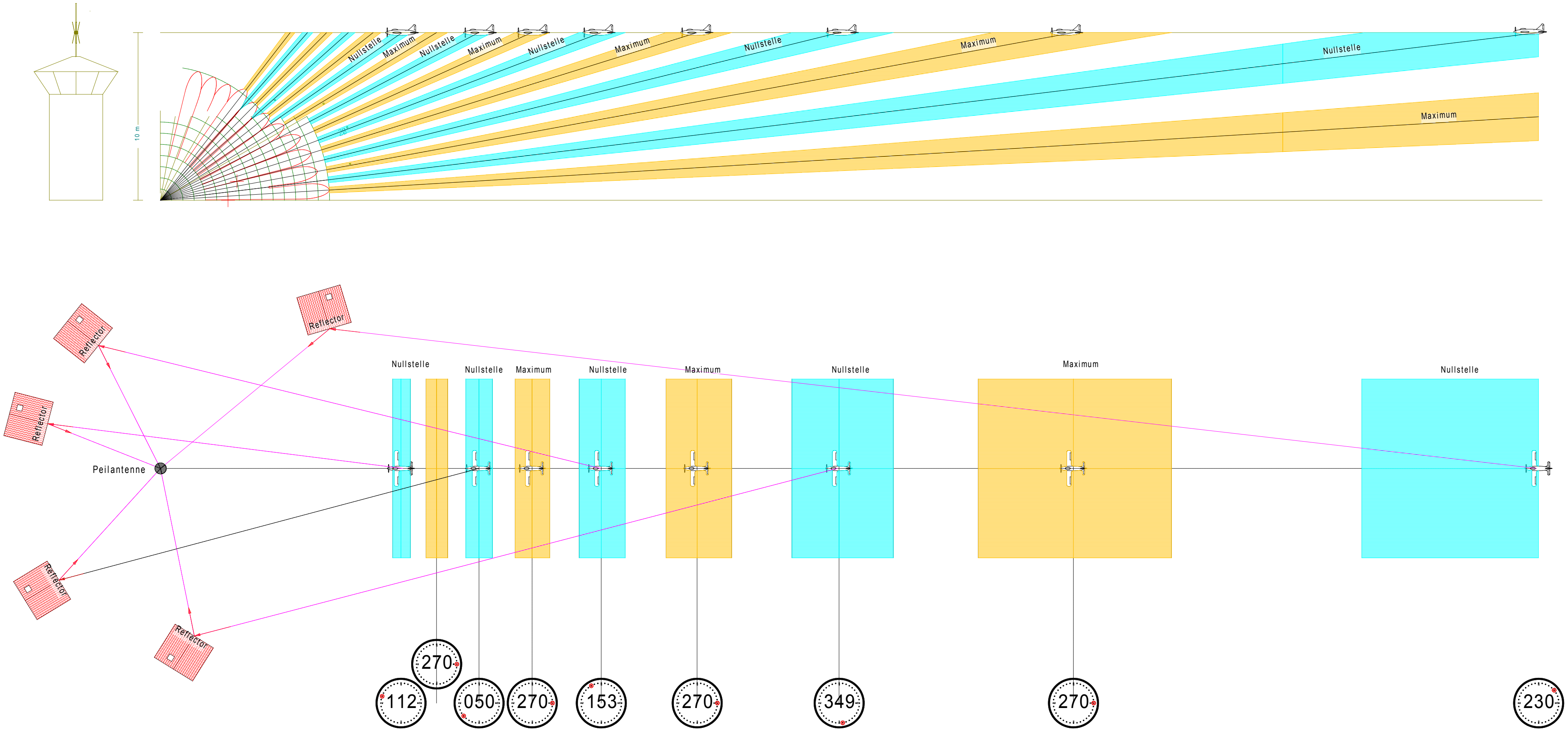
Due to the nature of radio waves, the radiation pattern of an antenna might even worsen the situation. In addition to objects, the ground on which the antenna is installed will also reflect radio waves. Those reflections are from the same direction as the signal source, but the signal path is longer than the direct signal path. Depending on the length of the path, and therefore depending on the angle of incidence of the reflected wave, the field strengths might be reduced or increased due to destructive or constructive influence. This section will show how this behavior can be influenced by selecting appropriate locations for the antenna.





Ground reflections will cause the vertical antenna diagram having zeros, i.e. angles at which the sensitivity of the antenna is extremely low. Higher antenna positions cause more zeros in the vertical antenna pattern.
If the direct wave is almost eliminated in a zero of the antenna pattern and the reflected wave is received in the maximum of the antenna pattern, it might happen that the reflected signal is nearly as strong, or even stronger at the antenna than the direct signal.
The best position for a DF antenna is on a flat surface at a distance from vertical reflectors, not more than circa 4 m above the ground.

2.2 Influence of Ground Reflections regarding Bearing Results



2.3 Influence of Radio Frequency Sources

Special care must be taken about the presence of radio transmitters. On one side, beside their wanted signal, radio transmitters (and even receivers) are allowed to transmit a certain amount of noise on other frequencies, potentially disturbing the reception at nearby receiving sites.
On the other side, receivers can only handle a certain level of signals close to the own receiving frequency. The causal effects are physical effects not identical for all combinations of receiving frequencies and the frequencies of the nearby transmitter.
Those effects are caused by the non-ideal behavior of real-word electronic components:

- Non-linearity of electronic components
- Noise produced by signal sources and amplifiers
- Finite filter attenuations

Those effects are mainly depending on

- The summary level of signal levels at the receiver input,
- The offset between receive frequency and signal frequency
- The level difference between wanted and unwanted signals.

That leads to the fact, that, theoretically, for each combination of transmitter and receiver frequencies, required distances would be different. Especially, if a lot of different transmitters might be active at the same time, predictions are difficult.
In most cases, even at distances of only around 100 m to a typical in-band transmitter of the aeronautical VHF service, influences will not exist. As for each combination of receive and transmit frequencies, the required distance will be different, worst-case scenarios are used to define distances to transmitters.

2.4 Site Selection Criteria

For uninfluenced bearing results, a direction finder antenna must be installed far away from any reflecting or absorbing structure, as described earlier in this document. The line of sight path to the transmitter including an area around (1^{st} Fresnel zone) should be without any absorbing or reflecting object, and no nearby reflector should be able to produce additional propagation paths. No objects at all in a 200 m circle, and restrictions for some types of installations up to a distance of several kilometers would be required.
In reality, in most cases, such an ideal site will not be available close to an airport.
However, practice shows that in reality, following some minimum recommendations will allow achieving usable results.
Those recommendations are found in the table “Distance to Obstacles and Noise Sources”.
The table below contains distance information for radio transmitters which will be satisfactory for most practically-encountered combinations. In only very few circumstances, especially if a high amount of transmitters active in parallel are installed close to the DF site, higher distances will be required.
If rules for core protection area, inner and outer restricted areas can be fulfilled on several possible installation sites, special care should be taken for external limitations. As far away they are, the better the location is. Noise generated by populated places, especially cities and industrial zones, reflections from steep slopes of mountains and signal attenuations due to forests are important aspects.

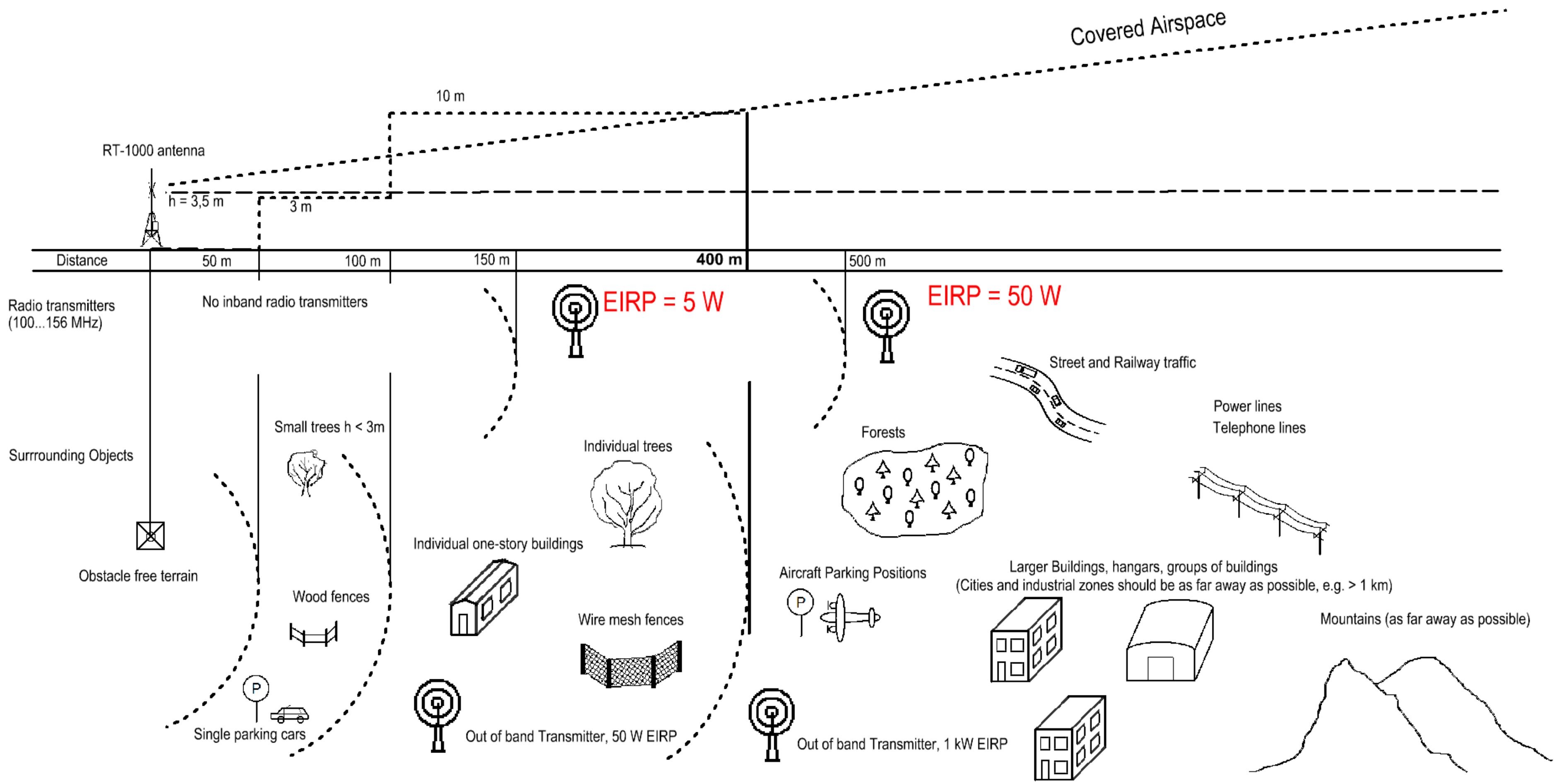
Distance to Obstacles and noise sources		
Parameter	**Condition**	**Data**
Core protection area	No objects	0 … 50 m
Inner restriced area	No large metallic objects (height >1m), no metallic fences, no buildings, no wire lines, no antennas, no trees or other non-metallic / non-conductive objects higher than ca. 3 m	50 … 100 m
Outer restriced Area	Single trees, wire fences, VHF/UHF antennas, non-metallic one-story buildings, parking cars etc, allowed. No aircraft parking positions, no hangars, no large buildings or groups of buildings, no forests, no power lines, no car traffic, nothing higher than 10 m and not within line of sight to targeted aircrafts.	100 … 400 m
External Limitations	Bridges, Buildings, High voltage power lines, Forrests, Hills, Mountains shall not be higher than the line of sight to targeted aircrafts. Mountains with steep rock slopes shall not be at higher elevations than ca. 3°. If several DF antenna positions are available, chose that one with the highest distance to cities, mountains and high voltage lines.	≥ 400 m
Distance to a 5 W EIRP in-band transmitter	Transmit frequency between 100 and 156 MHz, but more than 1 MHz offset to the receive frequency [1) 3)]	150 m [2)]
Distance to a 50 W EIRP in-band transmitter	Transmit frequency between 100 and 156 MHz, but more than 1 MHz offset to the receive frequency [1)]	500 m [2)]
Distance to out-of-band-transmitters, 50 W EIRP	Transmit frequency outside 100 to 156 MHz [1)]	100 m [2)]
Distance to out-of-band-transmitters, 1 kW EIRP	Transmit frequency outside 100 to 156 MHz [1)]	400 m [2)]

[1)] Desired signal field strength 26 dBµV/m (20 µV/m), Bearing error due to disturbances ≤ 2°, squelch shall not be opened due to disturbing signals (squelch set to 50%).

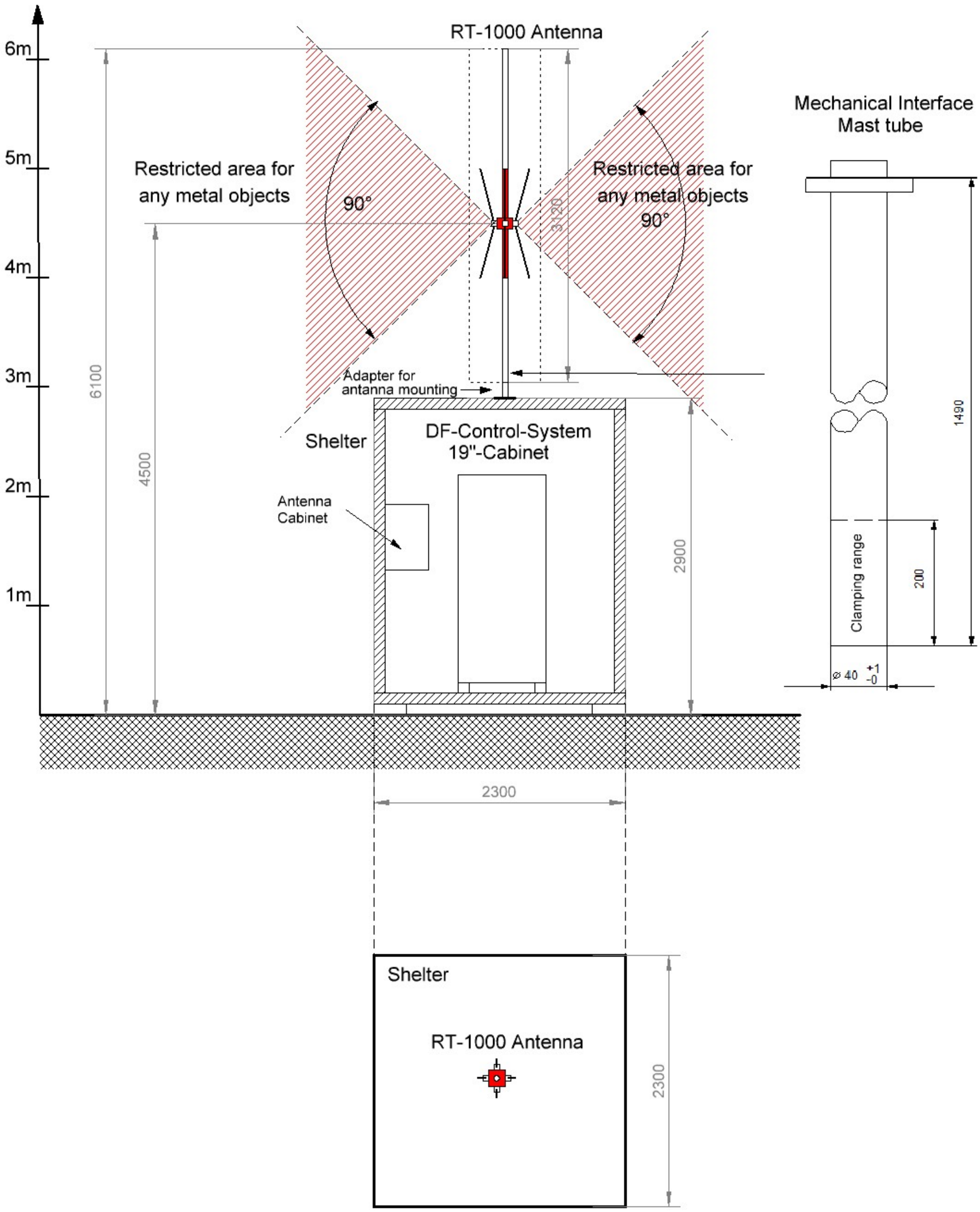
[2)] Declaration includes typical receiver properties of RT-1000 and typical spurious transmission characteristics of ground-based transmitters for the VHF aeronautical mobile service.
On very rare occasions, slightly higher distances might be recommendable.
That is, especially, true for 3rd order intermodulation (2 transmitters, frequency offsets between receive frequency, 1st transmitter and 2nd transmitter are equal, e.g. receiver on 125 MHz, transmitters on 126 MHz and 127 MHz).
In most cases, at distances greater than 100 m, already no disturbance will occur, but we recommend to contact RHOTHETA for further advice in such cases as well if the frequency offset to other transmitters is below 1 MHz or if 3rd order intermodulation might occur.

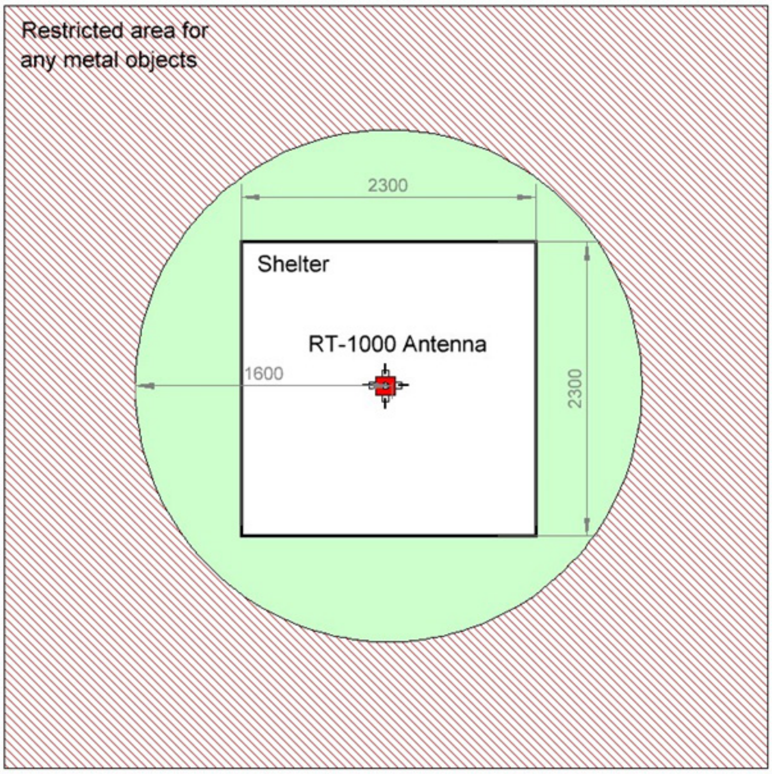
[3)] Rule additionally applies for VOR transmitters, as they use horizontal polarization, providing additional decoupling to the DF antenna.

2.5 Installation Site Requirements Regarding Distant Objects

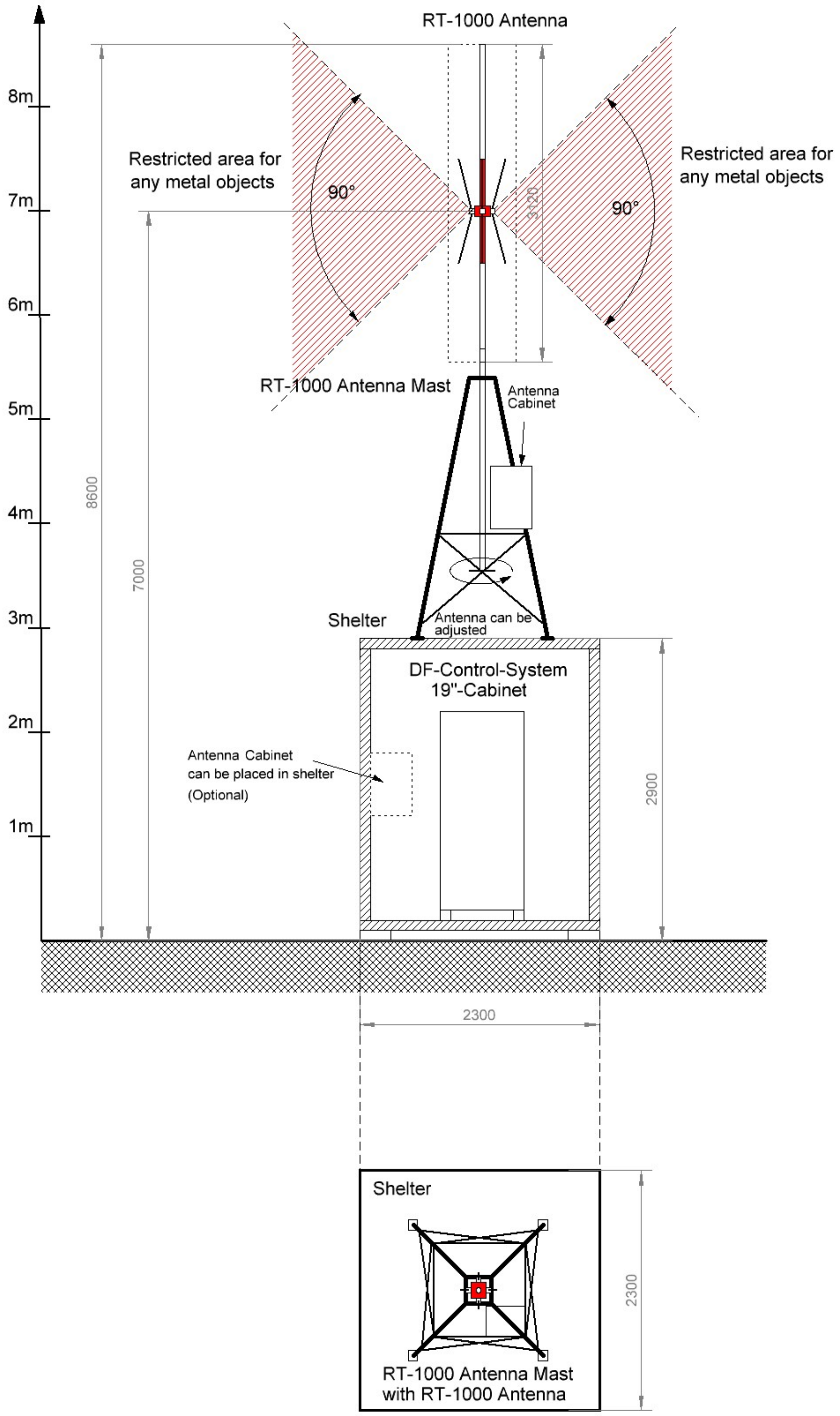


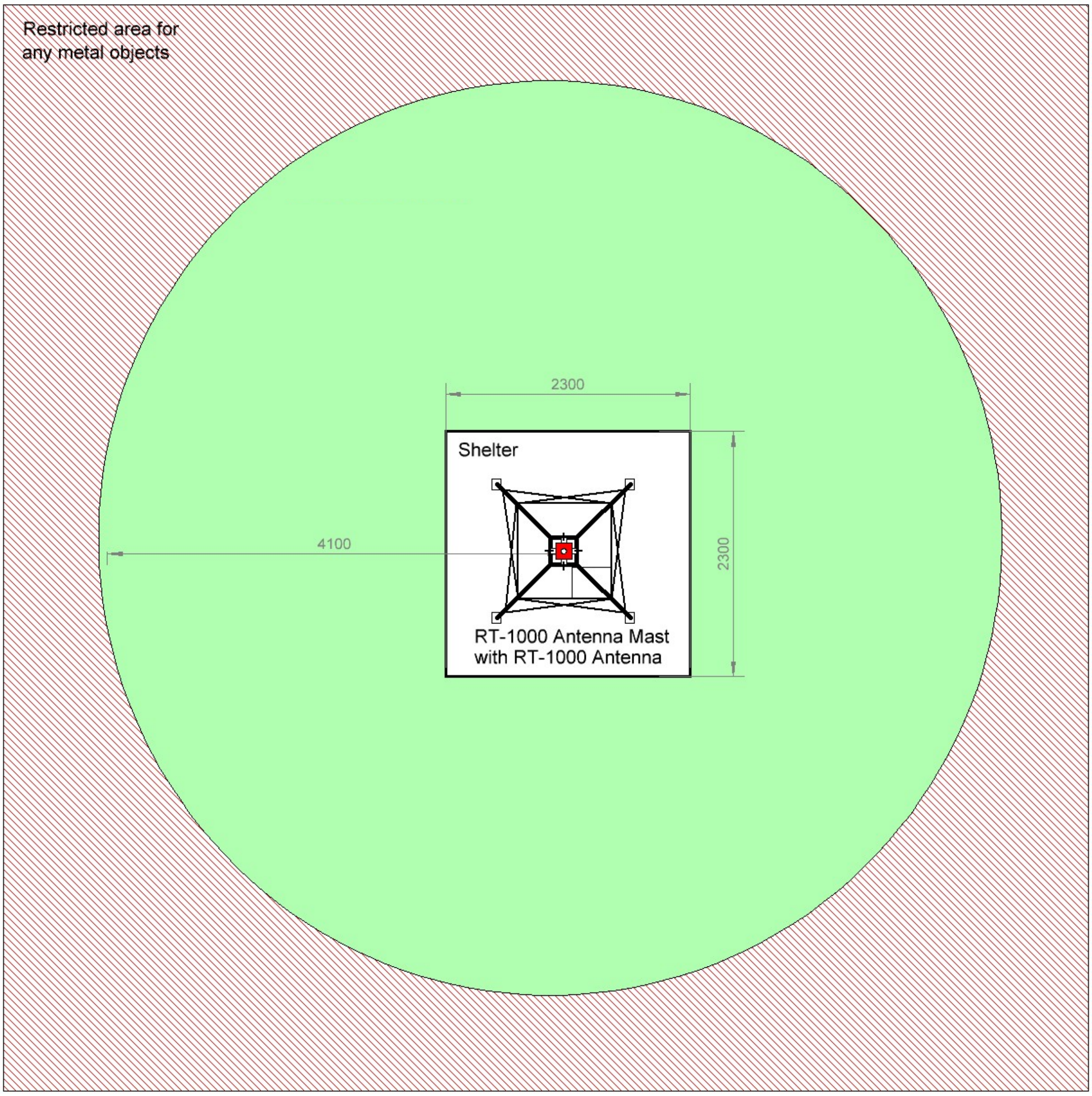
2.6 Installation Variant A: Antenna on Top of the Shelter




Restricted area for
any metal objects
2300
Shelter
RT-1000 Antenna
1600
2300

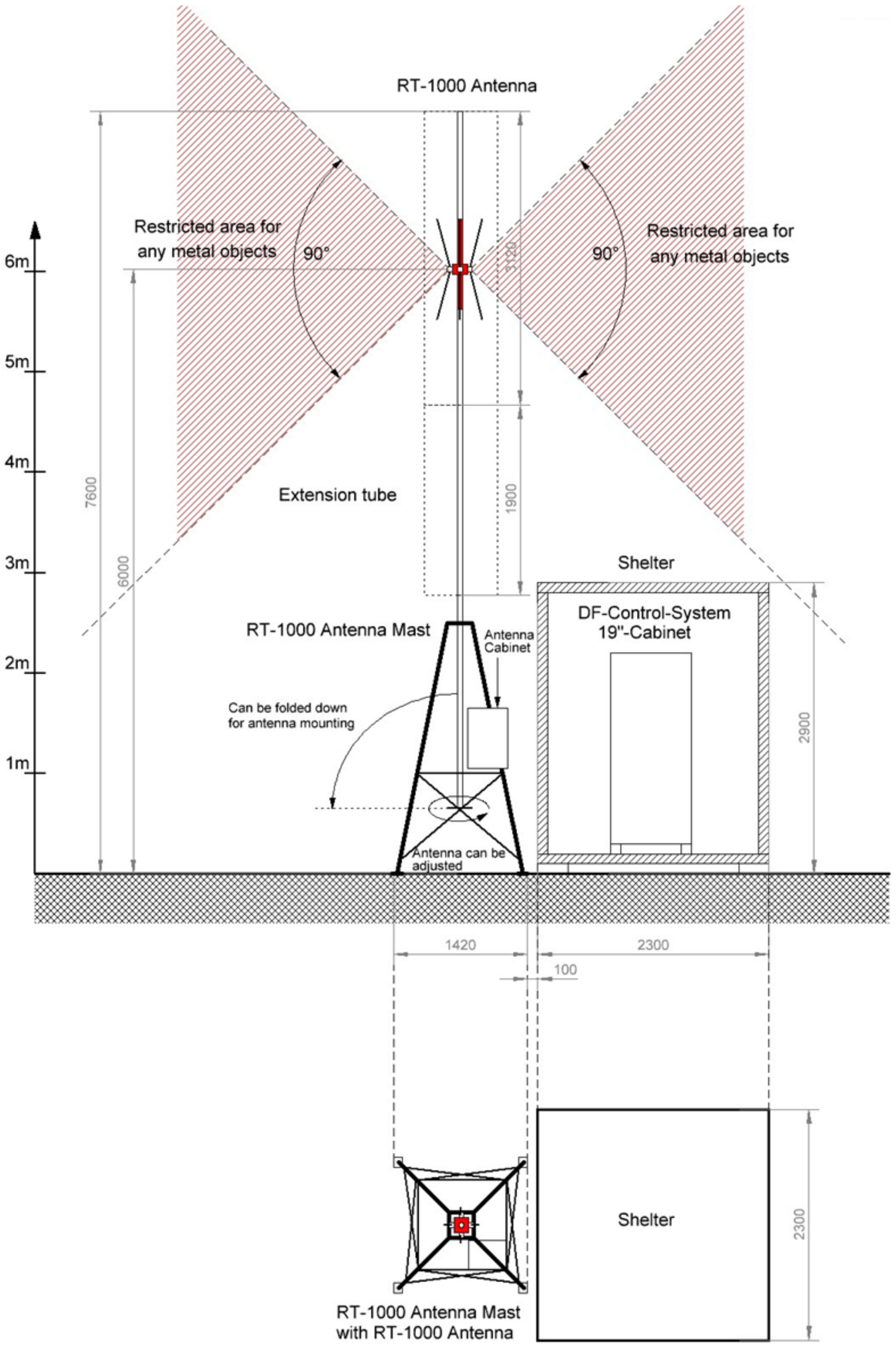
2.7 Installation Variant B: Antenna Mast with Antenna on Top of the Shelter

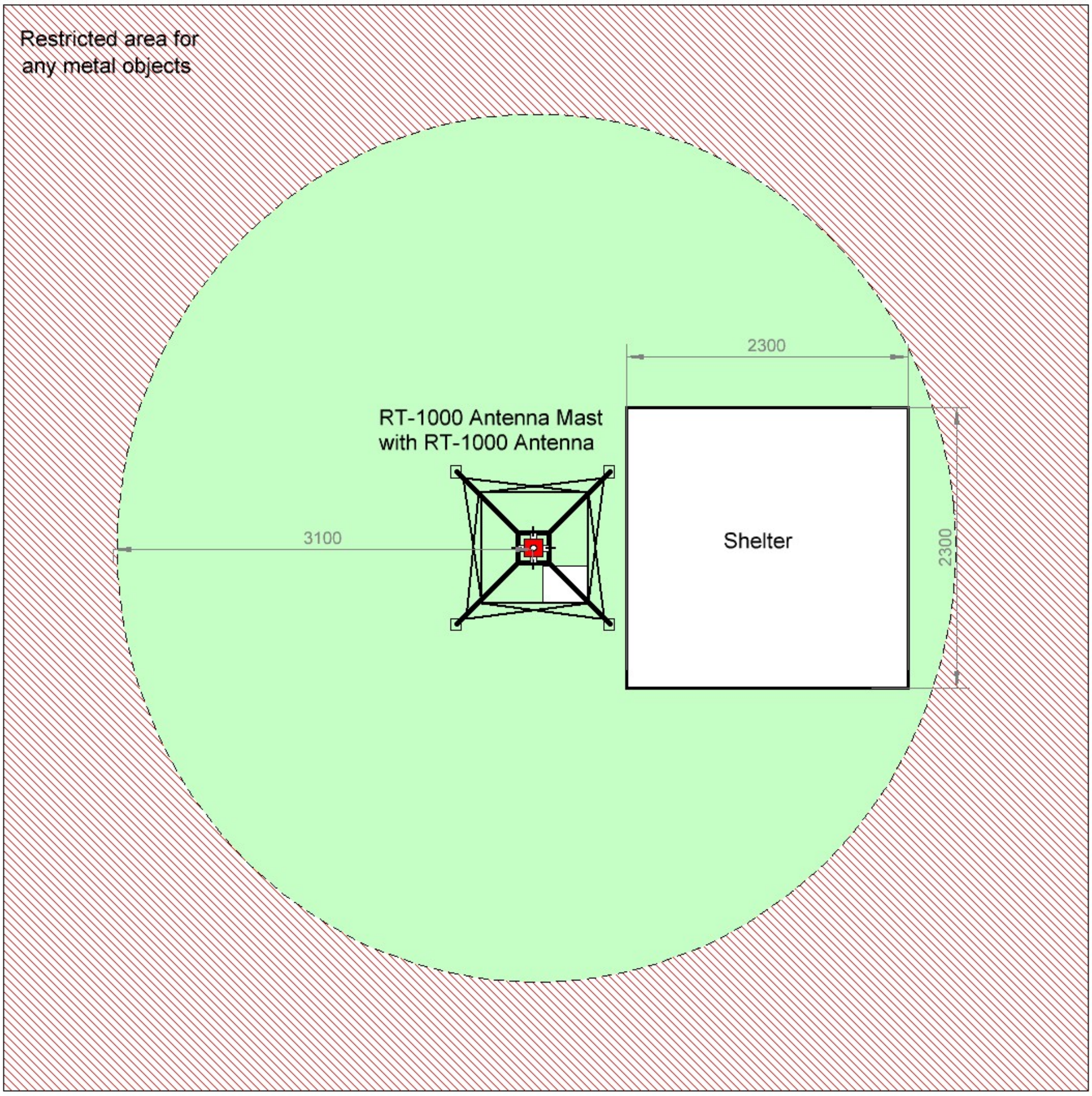



Restricted area for
any metal objects
2300
Shelter
4100
2300
RT-1000 Antenna Mast
with RT-1000 Antenna

2.8 Installation Variant C: Antenna close to the Shelter

The variant C is not recommended, due to the extended antenna height and the unsymmetrical installation of metal objects (shelter) around the antenna.
Use this variant only then, if variants A or B are not possible.




Restricted area for
any metal objects
2300
RT-1000 Antenna Mast
with RT-1000 Antenna
3100
Shelter
2300

2.9 Conclusion and Recommendation for ATC

From performance point of view all variants are possible. It is nevertheless strongly recommended to use the variant C only then, if variants A or B are not possible.

For Variant A: Antenna on top of the shelter

- The shelter should be as small as possible (Recommended dimensions 2,3x2,3x2,9 m)
- The optimal antenna position is in the middle of the roof

The antenna installation on top of the shelter is not prepared. The adapter for antenna mounting is not included, but RHOTHETA can solve the installation issue on demand.

For Variant B: Antenna mast with antenna on top of the shelter

- Due to the height of the antenna the dimensions of the shelter can be bigger
- The optimal antenna position is in the middle of the roof
- The shelter roof must carry the weight of the antenna mast including antenna (app. 120 kg)

All installation issues are solved with the ordering of a RT-1000 antenna mast, with exception of the weight allowance for the shelter roof.

For Variant C: Antenna near the shelter

- The Shelter should be as small as possible (Recommended dimensions 2,3x2,3x2,9 m)
- The antenna mast should be placed as close as possible to the shelter (app. 10 cm)
- The side on which the antenna should be attached, should be located on the side facing away from the shelter

All installation issues are solved with the ordering of a RT-1000 antenna mast. The extension tube and the antenna cable are included as well.

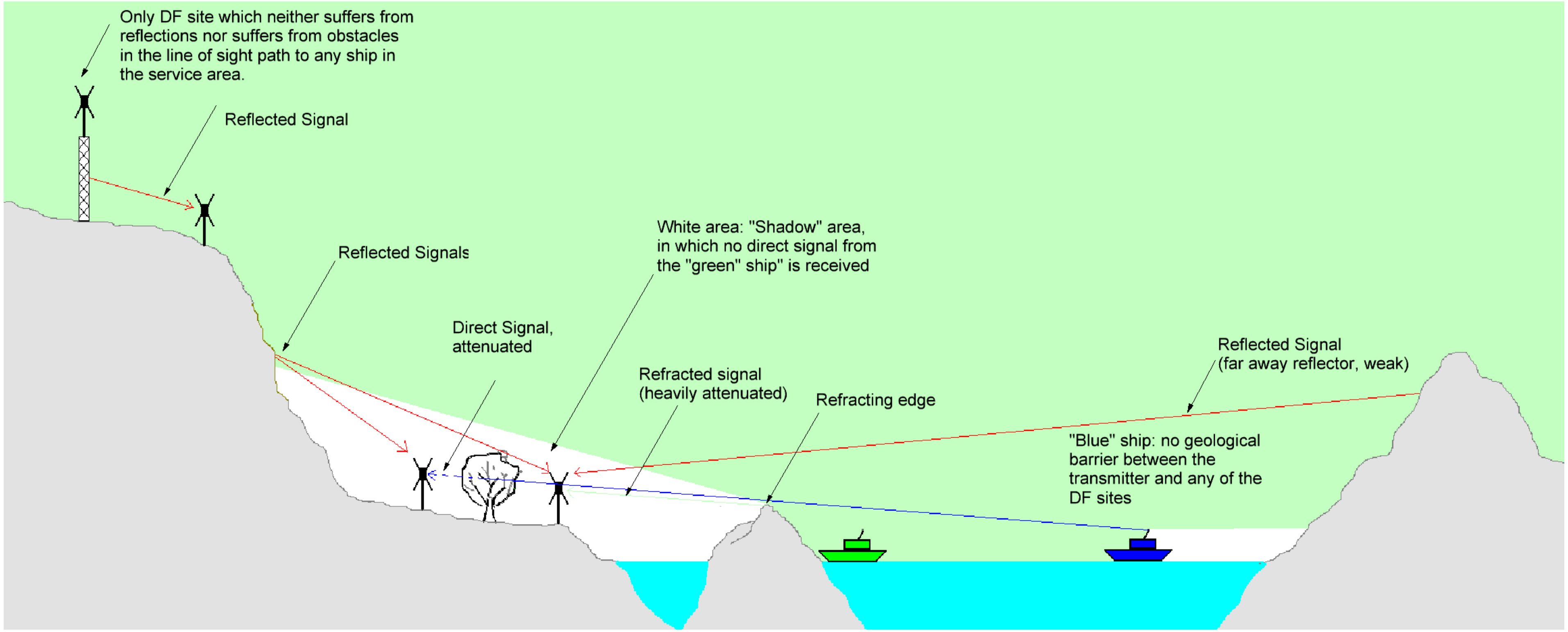
3 Recommendation for Vessel Traffic Service Installations

3.1 Influence of Reflections and Obstacles

Obstacles between the RT-1000 Antenna and the signal source (ship) will attenuate the signal received from the ship on a direct path.
Reflectors near to the RT-1000 Antenna will reflect the signal arriving at the reflector from the ship.
The measured angle of arrival of the signal will be a combination of the angle of the direct component of the electromagnetic field and the angle to the reflector.

- If the direct signal is significantly stronger than the reflected signal off another direction (indirect signal), the resulting bearing error will be small
- If the direct signal has approximately the same strength than the indirect signal, the resulting bearing will be somewhere between those directions, thus the error could be high.
- If the direct signal is weak compared to the reflected signal, the resulting bearing will show the direction to the reflector.
- If only a direct signal path exists, the resulting bearing will be the direction to the ship.

3.2 Visualized influence of direct and indirect signal paths



3.3 Influence of Radio Frequency Sources

Special care must be taken about the presence of radio transmitters. On one side, beside their wanted signal, radio transmitters (and even receivers) are allowed to transmit a certain amount of noise on other frequencies, potentially disturbing the reception at nearby receiving sites.
On the other side, receivers can only handle a certain level of signals close to the own receiving frequency. The causal effects are physical effects not identical for all combinations of receiving frequencies and the frequencies of the nearby transmitter.
Those effects are caused by the non-ideal behavior of real-word electronic components:

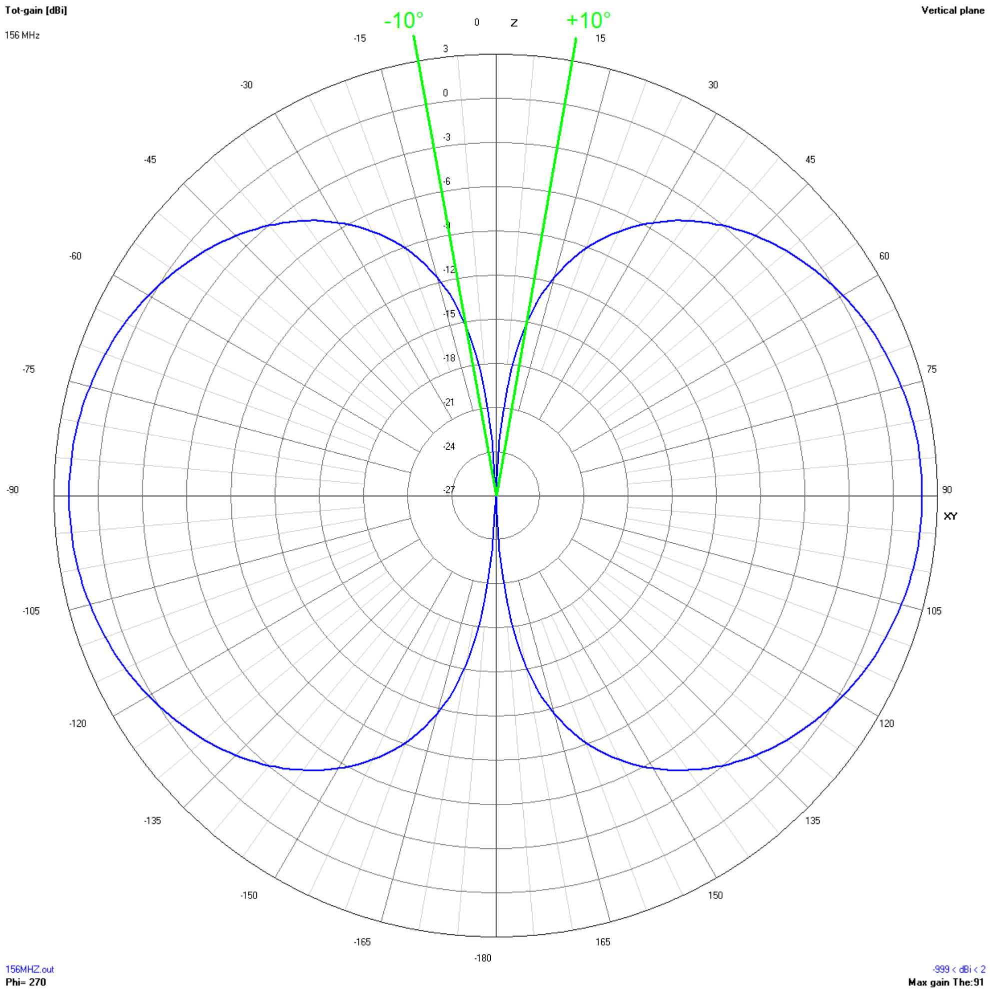
- Non-linearity of electronic components
- Noise produced by signal sources and amplifiers
- Finite filter attenuations

Those effects are mainly depending on

- The summary level of signal levels at the receiver input,
- The offset between receive frequency and signal frequency
- The level difference between wanted and unwanted signals.

That leads to the fact, that, theoretically, for each combination of transmitter and receiver frequencies, required distances would be different. Especially, if a lot of different transmitters might be active at the same time, predictions are difficult.
In most cases, even at distances of only around 100 m to a typical in-band transmitter of the maritime VHF service, influences will not exist. As for each combination of receive and transmit frequencies, the required distance will be different, worst-case scenarios are used to define distances to transmitters.

If all antennas are installed on a slim tower, nulls of the vertical radiation diagram of vertically polarized VTS communication antennas can be used to reduce the required distance
If this so-called “angle attenuation” cannot be used, for in-band transmitters, the required distance is a function of the radiated power.



The graph above shows the free space vertical radiation diagram (antenna gain in dBi vs. vertical radiation angle) of a typical sea band dipole antenna.
Within a cone of silence of ±10° off the vertical, the antenna gain drops below -15 dBi.
As long as the DF antenna is within this cone of silence, and together with its own (less distinct) cone of silence, required distances for interference-free operation might be reduced by factor 10, approximately, compared to horizontal separation distances.
Especially in the case of AIS transmitters, which are transmitting even while the VTS station is in receive mode for its dedicated voice communication channel, special care must be taken and sufficient separation distance been ensured to prohibit collisions.

For a typical EIRP of 10 W, the horizontal separation distance to an AIS transmitter should be more than 200 m. If vertical separation is given, less than 20 m will be sufficient.
If those conditions can’t be met, additional attenuation of the AIS signal is required through filtering between the antenna unit RTA-1300 and the direction finder.
Additionally, depending on the spectral purity of the AIS transmitter, additional filtering in the RF output of the AIS transmitter might be necessary.

3.4 Site Selection Criteria

For uninfluenced bearing results, a direction finder antenna must be installed far away from any reflecting or absorbing structure, as described earlier in this document.
The line of sight path to the transmitter including an area around (1^{st} Fresnel zone) must be without any absorbing or reflecting object, and no nearby reflector should be able to produce additional propagation paths.
No objects at all in a 200 m circle, and restrictions for some types of installations up to a distance of several kilometers would be required. Even far-away mountain slopes can produce a stronger signal by reflection than the direct path, if the signal source is beyond horizon. Any reflector behind or aside the mounting position (neither natural nor artificial) can add bearing errors.
In reality, in most cases, such an ideal site regarding reflectors and obstacles will not be available close to a coast line.
However, practice shows that in reality, following some minimum recommendations will allow achieving usable results.
Those recommendations are found in the table “Distance to Obstacles and Noise Sources”.
The table below contains distance information for radio transmitters which will be satisfactory for most practically-encountered combinations. In only very few circumstances, especially if a high amount of transmitters active in parallel are installed close to the DF site, higher distances will be required.
If rules for core protection area, inner and outer restricted areas can be fulfilled on several possible installation sites, special care should be taken for external limitations. As far away they are, the better the location is. Noise generated by populated places, especially cities and industrial zones, reflections from steep slopes of mountains and signal attenuations due to forests are important aspects.

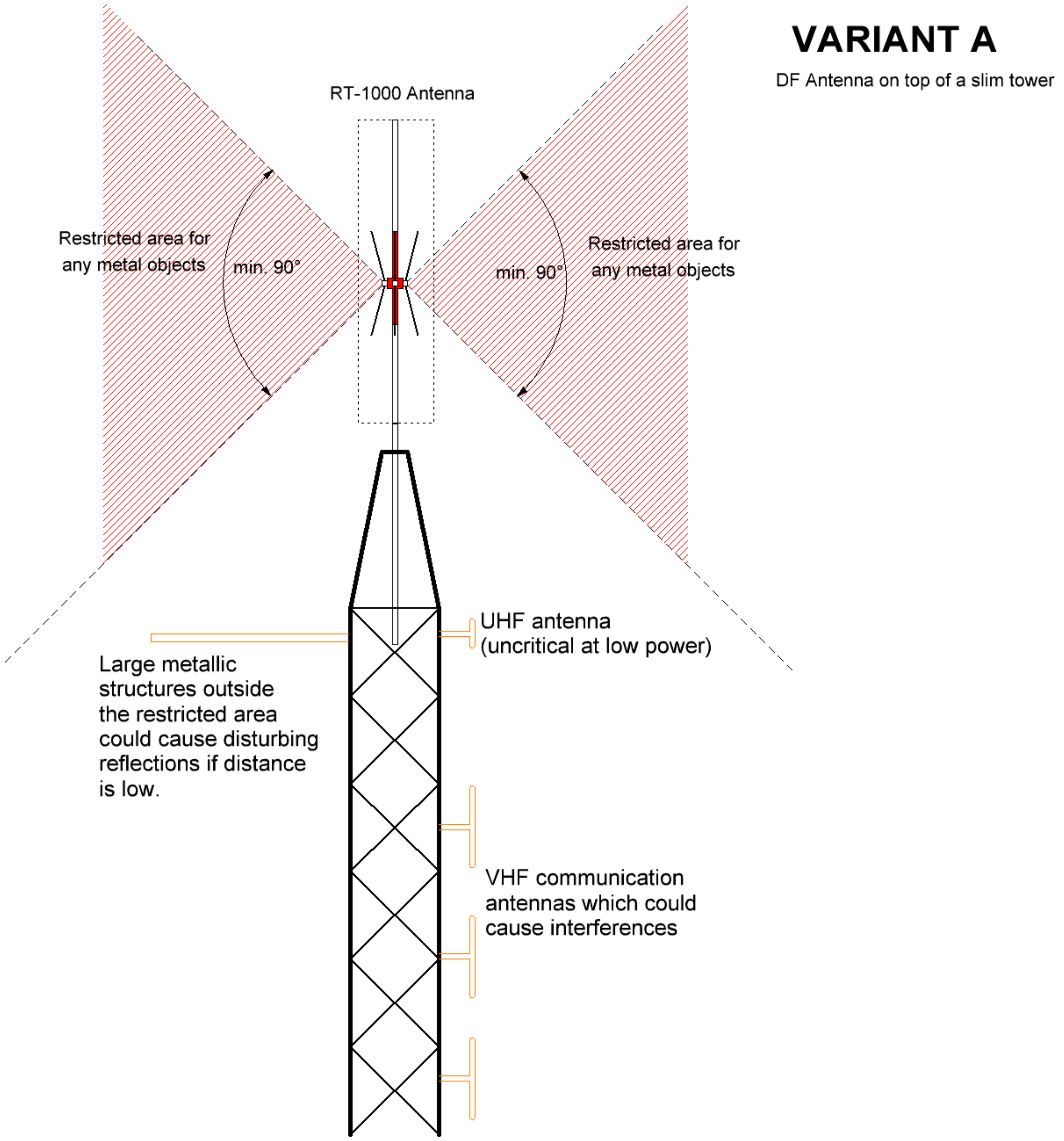
Distance to Obstacles and noise sources		
Parameter	**Condition**	**Data**
Core protection area	No conductive or absorbing objects within ±45° off the horizontal plane. No obstacles of any size in the direct line of sight to the service area. No large reflecting structures directly below the antenna outside ±45° off the horizontal plane.	0 … 50 m
Inner restricted area	No large metallic objects (size >1m), no metallic fences, no buildings, no wire lines, no antennas, no trees or other non-metallic / non- conductive objects higher than ca. 3 m within ±45° off the horizontal plane. No obstacles of any size in the direct line of sight to the service area.	50 … 100 m
Outer restricted Area	No buildings, towers, cranes, wind mills, hills etc. within ±45° off the horizontal plane. No obstacles of any size in the direct line of sight to the service area.	100 … 400 m

Distance to Obstacles and noise sources		
Parameter	**Condition**	**Data**
External Limitations	Bridges, Buildings, High voltage power lines, Forests, Hills, Mountains shall not be within the line of sight to targeted ships. Mountains with steep rock slopes or large vertical metal planes (metallic halls etc.) shall not be at higher elevations than ca. 5°. If several DF antenna positions are available, chose that one with the highest distance to cities / harbor installations, mountains and high voltage lines.	≥ 400 m
Horizontal distance to a 10 W EIRP in-band transmitter	Transmit frequency between 137 MHz and 186 MHz, but more than 1 MHz offset to the receive frequency [1)]	200 m [2)]
Vertical distance to a 10 W EIRP in-band transmitter	Transmit frequency between 137 MHz and 186 MHz, but more than 1 MHz offset to the receive frequency [1)]	20 m [2)]
Horizontal distance to a 50 W EIRP in-band transmitter	Transmit frequency between 137 MHz and 186 MHz, but more than 1 MHz offset to the receive frequency [1)]	500 m [2)]
Vertical distance to a 50 W EIRP in-band transmitter	Transmit frequency between 137 MHz and 186 MHz, but more than 1 MHz offset to the receive frequency [1)]	50 m [2)]
Distance to out-of-band-transmitters, 50 W EIRP	Transmit frequency outside 137 to 186 MHz [1)]	100 m [2)]
Distance to out-of-band-transmitters, 1 kW EIRP	Transmit frequency outside 137 to 186 MHz [1)]	400 m [2)]

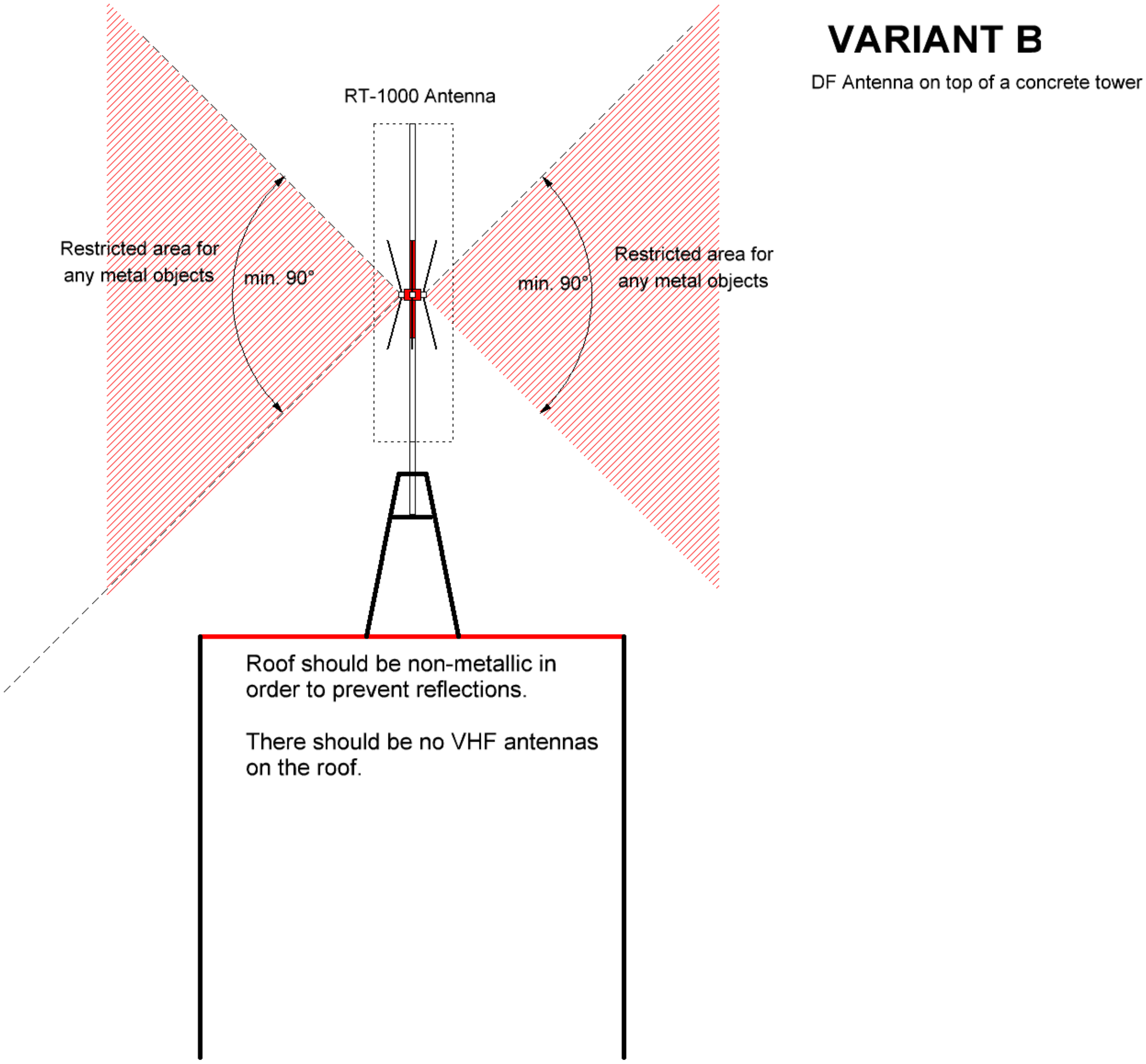
[1)] Desired signal field strength 26 dBµV/m (20 µV/m), Bearing error due to disturbances ≤ 2°, squelch shall not be opened due to disturbing signals (squelch set to 50%).

[2)] Declaration includes typical receiver properties of RT-1000. On very rare occasions, slightly higher distances might be recommendable.
That is, especially, true for 3rd order intermodulation (2 transmitters, frequency offsets between receive frequency, 1st transmitter and 2nd transmitter are equal, e.g. receiver on 156 MHz, transmitters on 157 MHz and 158 MHz).
In most cases, at distances greater than 100 m in the horizontal plane, already no disturbance will occur, but we recommend to contact RHOTHETA for further advice in such cases as well if the frequency offset to other transmitters is below 1 MHz or if 3rd order intermodulation might occur.

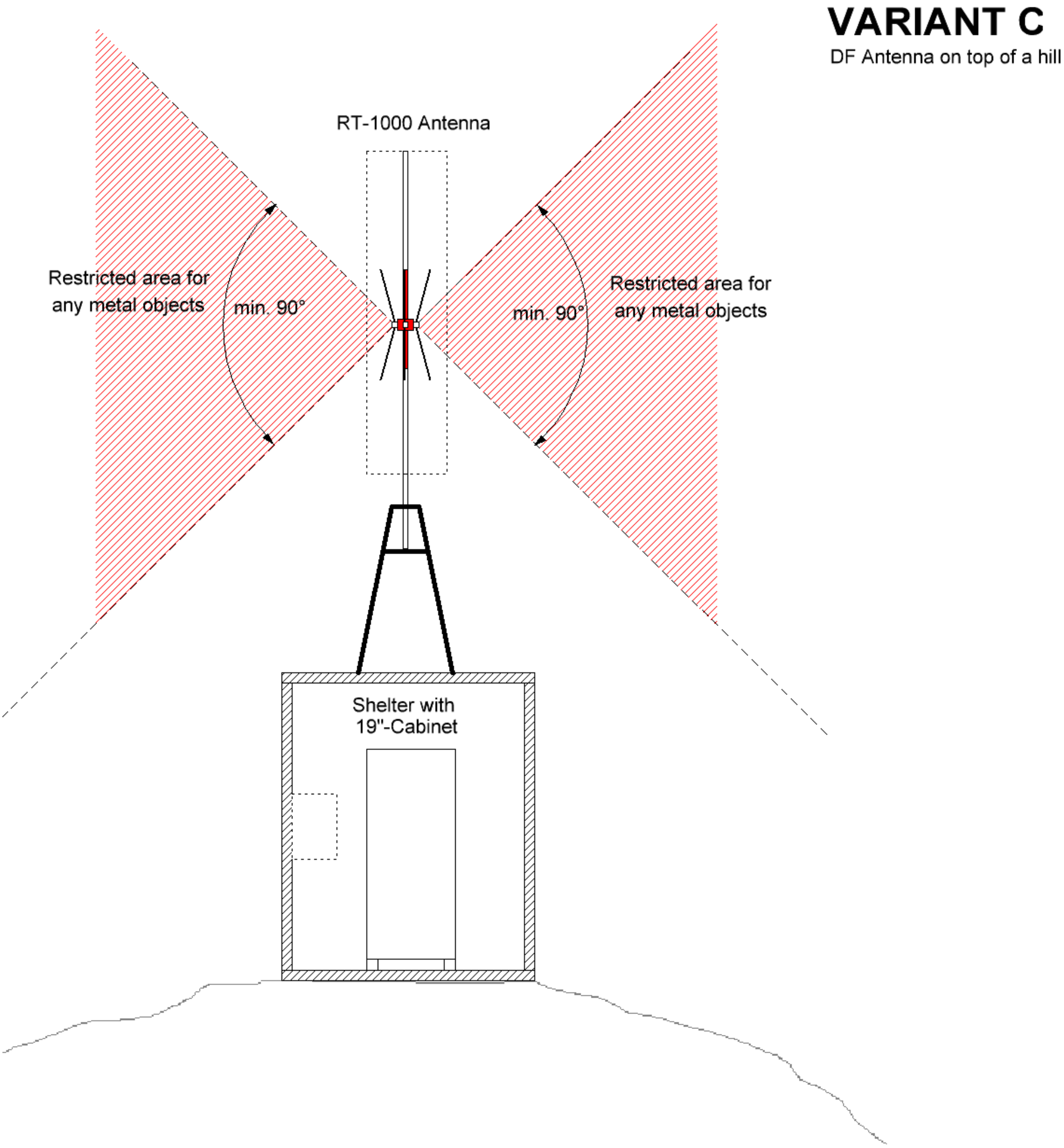
3.5 Installation Variant A: Antenna on Top of a Mast



3.6 Installation Variant B: Antenna on Top of a concrete Building



3.7 Installation Variant C: Antenna and Shelter on Top of a Hill



3.8 Conclusion and Recommendation for VTS

All three variants, installation on top of a mast or installation on top of a building or on a hilltop site, are possible.
Variant A and C are better, in the case of variant A, the best site would be a hilltop site, too.

For Variant A: Antenna on top of a Mast

- The Mast should be high as possible.
- The antenna shall be on top of the mast
- A mast-mount shelter for the 19” cabinet should be used to keep cables short.
- Other vertically polarized VHF communication antennas should be mounted as close to the mast and as far away from the top as possible.
- Well-shielded coaxial cable should be used if the cable path is near to transmit antennas.

For Variant B: Antenna on top of a concrete building

- There should be no other metallic installations, especially no VHF antennas, on the roof.
- The optimal antenna position is in the middle of the roof

For Variant C: Antenna with shelter on top of a hill

- Due to the height of the antenna, the dimensions of the shelter can be bigger
- The optimal antenna position is in the middle of the roof
- The shelter roof must carry the weight of the antenna mast including antenna (app. 120 kg), otherwise, non-standard installation means must be defined.

All installation issues are solved with the ordering of a RT-1000 antenna mast, with exception of the weight allowance for the shelter roof.