WAPA

WIRELESS HIGH SITE ENGINEERING GUIDELINE

CHANGE HISTORY

REVISION	DATE	DESCRIPTION OF CHANGE
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1. INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide an engineering guideline to WAPA members in the selection, design, construction, installation and maintenance of high sites.

1.2 BACKGROUND

In the course of provisioning wireless access services, WAPA members, as telecommunications operators and referred to hereafter as "operators", whether they are High Site Owners or Tenants, make use of wireless high sites from which to provide wireless connectivity to their clients and usually to also backhaul client traffic wirelessly to other points of presence. High sites can vary in nature from rooftops to towers and masts (guyed towers) making use of different types of structures on sites. Rights to install equipment are granted to operators through rental agreements with building owners, site owners, and tower owners or as a consequence of the construction of new towers on their own property. The term "high site" therefore covers a wide range of implementations.

The rapid growth in the use of wireless technologies for public and enterprise telecommunications has led to the significant increase in the number of high sites that have been established, and to the increased sharing of high sites, with operators competing for the best equipment positions on sites and on structures.

Radio frequency spectrum is a limited resource and the very nature of the technologies that WAPA members, as operators, tend to use, namely the licence-exempt band technologies, implies a high demand for a limited number of channels/frequencies. This together with the increased sharing of high sites and structures can lead to high levels of interference between collocated equipment.

The construction and operation of wireless technologies and high sites are governed by various acts of legislation relating to aspects including:

- Telecommunications regulation;
- Health and safety;
- Civil aviation;
- Environmental impact management; and,
- National and local authority building standards and regulations.

Ignorance of and/or non-compliance with any regulations relating to the above can result in serious punitive measures being taken against offending operators (as well as High Site Owners).

In addition, the construction and operation of high sites is impacted by broader environmental issues such as adverse weather conditions, poor access to sites, radio frequency interference from surrounding areas, poor electrical power, lightning, poor soil conditions, corrosive atmospheric conditions, etc.

Guidance based on industry best practices in the selection, planning, construction, installation and operation of high sites will assist in avoiding, or at least in minimising the impact of the above issues.

1.3 SCOPE

The scope of this document is limited to providing engineering guidance based on industry best practices as are applicable to the types of equipment likely to be used by operators, namely point-to-point and point-to-multipoint equipments, operating in both licensed and licence-exempt bands.

Several codes of practice for high site engineering exist. Some of these codes are identified here:

- SANS 1135:2011 Code of Practice for Wireless High Site Engineering (draft);
- ETSI EG 200 053 v1.5.1, Electromagnetic compatibility and Radio Spectrum Matters (ERM); Radio site engineering for radio equipment and systems;
- MPT 1331 Code of Practice for Radio Site Engineering;
- Motorola R56 Standards and Guidelines for Communication Sites; and,
- MA-COM Specifications, Guidelines, and Practices: Tower Requirements and General Specifications.

Unfortunately most of these are either too broad, too specific, aged, not approved yet or generally not suitable for the typical independent wireless operator.

The engineering guidance provided in this document is therefore focussed on high site and equipment-related industry best practices that are appropriate for the following technologies:

Point to Multipoint Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands.

Point to Point Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands.
- Licensed bands: typically 6 to 38GHz bands.

Wireless equipment for these applications is built to standards that have been created to ensure the efficient use of the radio spectrum. These standards specify appropriate performance parameters for transmitters, receivers and antennas. Good installation design will ensure that, as far as possible, the performance of a complete installation will preserve the performance characteristics of the components, will result in the intended field strength in the designated area, and will avoid co-channel and adjacent channel interference.

Good engineering design will also ensure that preventive and corrective maintenance can be carried out safely and with a minimum of down-time, to ensure that the installation will continue to meet the performance criteria as intended.

This document follows the logical sequence that would be adopted in the provision of a new high site, from the development of a new site, the construction of the site, the selection and installation of the equipment, the maintenance of the site and equipment, and the administration of the site. Consideration is also given to health and safety requirements that need to be adopted.

1.4 OBJECTIVE

The objective of this document is to identify industry best practices which will support the provisioning of wireless access and backhaul services of a high standing and fulfilment of end-user requirements. Specific objectives include the follow:

- To obtain the coverage throughput required from the chosen site in a precise and well defined manner;
- To minimise spectrum pollution to other operators on adjacent sites;
- To minimise interference to other collocated operators;
- To operate systems with the effective isotropic radiated power (EIRP) and optimum spectral efficiency compatible with providing the required service;
- To minimise the effects of lightning; and,
- To operate the site safely, as is required by relevant legislation.

To fulfil the requirements of all relevant legislation and recommendations, the above criteria should be met for the whole of the working life of the installation and should allow for future expansion. The quality of service is largely dependent on the planning of the system. The broad objective is to assure growth in, and sustainability of, the wireless access services market.

2. REFERENCES

a) Civil Aviation Act No. 13 of 2009;

b) Regulations (GN R 544, 545, 546) (in terms of the EMA Act);

c) National Environmental Management Act 107 of 1998 (the 'NEMA Act");

d) National Water Act 36 of 1998;

e) NEM: Protected Areas Act 57 of 2003;

f) NEM: Biodiversity Act 10 of 2004;

g) SABS 0160-1, *Wind Design Code – Part 1*;

h) SABS 0162-1, *Structural Code – Part 1;*

i) SABS ISO 1461, *Hot Dip Galvanising*;

j) SANS 657-1, *General Steel Tubing*;

k) SABS 1431, *Material Standards*;

l) SANS 10400, *National Building Code;*

m) SANS 10142-1, *The wiring of premises, Part 1: low-voltage installations;*

n) SANS 10313, *Protection against lightning – Physical damage to structures and life hazard*;

o) SANS 10199, *The design and installation of earth electrodes*;

p) SANS 62305-1/IEC 62305-1, *Protection against lightning – Part 1*;

q) SANS 62305-2/IEC 62305-2, *Protection against lightning – Part 2;*

r) SANS 62305-2/IEC 62305-2, *Protection against lightning – Part 3;*

s) SANS 62305-2/IEC 62305-2, *Protection against lightning – Part 4;*

t) IEEE 802.11 a/b/g/n

u) Government Gazette No. 32769, dated 2 December 2009, Notice 1597 of 2009;

v) Government Gazette No. 34172, dated 31 March 2011, Notice 184 of 2011;

w) Government Gazette No. 36336, dated 28 June 2013, Notice 354 of 2013;

x) Occupational Health and Safety Act No. 85 of 1993;

y) Compensation for Occupational Injuries and Diseases Act 130 of 1993;

z) Government Gazette No. 37305, dated 7 February 2014, *Construction Regulations, 2014*;

aa) SANS 10133-1, Industrial Rope Access, Part 1: *Worksite procedures;*

bb) SANS 10133-3, Industrial Rope Access, Part 3: *Inspections, certification and management procedures for equipment*;

cc) ICNIRP GUIDELINES *for limiting exposure to time-varying electric, magnetic and electromagnetic fields 9up to 300GHz);*

dd) SANS 1186-1, Symbolic safety signs – Part 1, *Standard signs and general requirements*;

3. HIGH SITE DEVELOPMENT

3.1 INTRODUCTION

The engineering guidance provided in this document is focussed on high site and equipment-related industry best practices that are appropriate to the types of equipment likely to be used by operators, namely point-to-point and point-to-multipoint equipments, operating in both licensed and licence-exempt bands, as summarised here:

Point to Multipoint Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands.

Point to Point Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands.
- Licensed bands: typically 6 to 38GHz bands.

In the selection of a site (ie the location) for the development of a new high site, it is critically important to consider all aspects of site selection and site layout and design. Poor site selection and design cannot necessarily be remedied with a realistic amount of equipment engineering. In the site selection process, the location of the intended service area, desired service parameters and service performance levels, the propagation characteristics of the frequencies to be used, various legal aspects and environmental considerations need to be taken into account. A similar situation applies when an operator wishes to consider the use of an existing high site for the expansion of an existing network or the development of a new network.

Various types of structures are available and consideration should be given to the nature of the equipment to be installed, physical characteristics of this equipment, maintenance requirements, future requirements, environmental conditions, etc. Again, attention should be given to measures that will minimise interference, and increase maintainability and reliability.

All site activities and design processes, from initial site visits through construction to on-going maintenance and site inspections, shall be carried out with due attention to the various health and safety aspects that apply. Refer to **Section 8 Health and Safety** for further details.

3.2 SITE SELECTION

3.2.1 SELECTION PROCESS

In the selection of a suitable site, the primary objective is to identify a site that will enable radio frequency coverage of a particular area for the delivery of a specific service. Potential sites include mountains, hilltops, buildings and other forms of structures or potential structures. The first step therefore is to identify potential high sites from which coverage could be achieved. The next step then is to qualify each of these potential sites against a set of criteria which includes aspects such as line of sight, height of site, site sharing, propagation considerations, site access, site services, and environmental management considerations, as detailed hereafter.

3.2.2 LINE OF SIGHT

A potential site should ideally provide a clear line of sight to the area of intended coverage. However, the deleterious effect of nearby obstructions and clutter should be considered. At the same time, the beneficial impact of natural obstructions on reducing co-channel interference should also be considered. Typically, the systems to be installed by independent wireless operators are designed on an interference-limited basis rather than on a noise-limited basis.

Three approaches can be taken to make an initial evaluation of the potential line of sight from a candidate high site to the intended area of coverage. The first approach is to visit the site physically and to make a judgement call based on what is optically visible. However this may not always be practical if the site is inaccessible or the line of sight is cluttered from ground level but not from an elevated height (such as a projected tower). The second approach to consider is the use of topographical maps where, by studying the contour lines one can establish the benefit of a potential site. The third approach is to make use of Google Earth or a similar tool. By making use of the elevation view facility, one can, with a sample of bearing lines, make a relatively quick judgement as to the potential benefit of the candidate site.

3.2.3 HEIGHT OF SITE

A potential site should be adequately high to provide coverage for current requirements and anticipated future requirements, but not excessively high, in order to avoid co-channel interference from other sites.

3.2.4 SITE SHARING

Consideration should be given to the sharing of existing nearby sites rather than the development of new sites. Alternatively, if the construction of a new site is deemed necessary, consideration should be given to inviting other operators to share the new site as a means of sharing the costs of the new site and of minimising the number of sites built. The needs of potential users in the future should also be taken into account in the initial planning of a new site.

In the case where an existing high site has been identified as a suitable new high site for an operator, some options exist in terms of how the operator can make use of the new site. These include the possibility to:

a) Share an existing tower or construct a new tower; and,

b) Share an equipment shelter or construct a new equipment shelter.

In the case of new structures, permission is generally required from the Commissioner for Civil Aviation, as discussed in **Section 3.2.9 Civil Aviation Requirements** below.

The advantages and disadvantages of each option should be carefully evaluated. Compatibility between planned and existing facilities may only be achievable with a complete site redevelopment. In such a situation, it may be preferable to consider an alternative site.

3.2.5 PROPAGATION CONSIDERATIONS

To design installations which meet the user's expectations, the requirements must be understood and interpreted in the context of the propagation parameters of the frequencies to be used. In certain environments it may be extremely difficult to provide a clear path for the required radiation pattern at the relevant frequency.

Propagation analysis is necessary to confirm the suitability of an existing site, or to decide on the exact location for the construction of a new radio site. Propagation analysis requires the use of a propagation planning tool together with the use of digital terrain maps and clutter maps as well as vector files of terrain features such as roads, borders etc. Such planning tools range in complexity from relatively simple tools which make use of coarse grained terrain maps to relatively complex tools which make use of high resolution terrain maps and carved morphology maps, and incorporate prediction models that consider multiple levels of morphology.

Equipment vendors usually provide access to relatively simple tools free of charge, which can provide adequate answers for the selection of high sites. Additional information that is required for propagation prediction includes information such as the proposed transmit power, frequency band, antenna types, antenna gains, antenna heights, receiver sensitivity and type of the system in use.

The characteristics of an existing site can also be judged from the experience of current operators of existing sites as well as an understanding of the current services being offered from existing sites. A prediction of likely performance can be established by implementing a temporary installation and carrying out field measurements. The most reliable information is obtained by the establishment of a CW test station and measurement of signal strength across the area of interest. Such tests should be carefully executed to simulate the user's final operational conditions.

3.2.6 RADIO FREQUENCY COMPATIBILITY

The selection of a new site should take into account the nearby location of other wireless transmissions which have the potential to interfere with the equipment to be installed. The converse also applies in that consideration should also be given to the possibility of interference being caused by the new equipment to existing equipment in close proximity. In addition, the selection of a new site should also take into account the possibility of interference from sources of man-made electrical noise generated in nearby industrial sites. In the event that a high level of interference is predicted, then an alternative site should be considered.

3.2.7 SITE ACCESS

To maintain a high availability of a wireless service from a particular high site, it is inevitable that physical access to the site on a 24x7 basis is required. The ability to access the site by road under all weather conditions should be evaluated, including extreme conditions of snow and swollen rivers. The cost and legal implications of improving the road access should also be evaluated.

Access to sites is often through the property of third parties and in such circumstances, the operator will have to obtain land owner consent independently of any high site lease agreement that the operator may enter into with the High Site Owner.

3.2.8 SITE SERVICES

The availability of electrical power on a site has to be taken into account. The existing electrical installation should have sufficient excess capacity for the envisaged equipment. Alternatively the cost of extending reticulated power to the site or an alternative source of electrical power should be evaluated.

3.2.9 CIVIL AVIATION REGULATIONS

Within the scope of the ***Civil Aviation Act No. 13 of 2009 and it's Regulations***, any communications structure, building or other structure, whether temporary or permanent, which has the potential to endanger aviation in navigable airspace, or has the potential to interfere with the operation of navigation or surveillance systems or Instrument Landing Systems, including meteorological systems for aeronautical purposes, is considered an **OBSTACLE.** There is therefore an obligation to submit details of any such proposed structure to the Commissioner for Civil Aviation for evaluation. Further information is available on the South African Civil Aviation Authority (SACAA) website at www.caa.co.za under Obstacles/Objects Affecting Airspace. The application form can be accessed on-line on the SACAA website site at www.caa.co.za under Obstacles/Obstacle forms.

3.2.10 ENVIRONMENTAL MANAGEMENT REGULATIONS

In terms of the ***National Environmental Management Act 107 of 1998*** ('the NEMA Act"), specified activities within the scope of the construction, operation and closure/decommissioning of a high site outside of an urban area, may be deemed to be "listed activities" depending upon the details and nature of the target area. The definitions of these target areas vary from province to province and reference needs to be made to ***Regulations (GN R 544, 545, 546)*** in terms of the NEMA Act. The affected activities include:

- The establishment of a new site;
- The construction of a new access road and/or expansion or upgrading of an existing access road; and
- The construction of masts or towers of any material or type used for telecommunication broadcasting or radio transmission purposes where the mast (or tower):
  a) Is to be placed on a site not previously used for this purpose; and
  b) Will exceed 15 metres in height,

  but excluding attachments to existing buildings and masts (or towers) on rooftops.

"Listed activities" require an environmental impact assessment to be carried out and approvals to be granted. These can be lengthy processes that may result in certain constraints or conditions being applied. Further, depending on the specific site characteristics, further approvals in terms of the ***National Water Act 36 of 1998***, the ***NEM: Protected Areas Act 57 of 2003*** and the ***NEM: Biodiversity Act 10 of 2004*** may also be required.

These requirements affect both public and private land, as within the scope of environmental management, private land is regarded as part of the environment and the purpose of the NEMA Act and other associated Acts is to protect the environment. Special requirements for toilets, waste management, river crossings, and the storage and transportation of diesel fuel and oil, also exist. Overall, the requirements are extensive and require specialist knowledge and skills, and a competent authority who is an environmental assessment practitioner shall be appointed. Hefty fines can be imposed if these regulations are transgressed.

Whilst the site should have sufficient capacity for the foreseeable requirements, the impact on the environment could be minimised in various ways. Examples include:

a) Relocation of the site a small distance away without any change to the performance of the site;

b) Minimization of the number of antennas, careful choice of antenna types and their arrangement in a symmetrical form, subject to a satisfactory radio frequency performance;

c) Use of an alternative type of support structure with a more acceptable profile;

d) Use of various materials, styles and colours for construction of equipment buildings with a more acceptable appearance; and,

e) Improvement in the visual impact of the site the addition of trees and shrubs.

Consideration should be given to the choice of an alternative site if the cost and timescale implications of compliance with these legal requirements are not acceptable.

3.2.11 FINAL SELECTION

The final selection of a site is likely to be a compromise between wireless coverage requirements, technical considerations and economic or planning constraints.

The selection of suitable sites is an iterative process that may have to be repeated several times to produce the optimum short list of potential sites. It is also an interactive process where the selection of one site may eliminate the selection of another due possibly to aspects such as constraints on the backhaul design or financial packaging, or close proximity of alternative sites.

3.3 SITE LAYOUT DESIGN AND DEVELOPMENT

3.3.1 LAYOUT DESIGN

Having selected a suitable site for a new high site, the next step is to design the layout of the site whether it is a green field site, existing site, existing building or a site where a new structure is required. In designing the layout of a site or the additions to an existing site, whether it is a building or other form of structure or number of structures, the design of the layout of should take into account the desired coverage areas, the types of systems to be used, the nature of any natural obstructions or existing structures on or in the proximity of the site, new or existing access roads, topography of the site, clutter on or in the vicinity of the site, etc. Specific attention in the design of the layout should be given to the need to minimise or preferably avoid co-channel and adjacent channel interference. Several aspects are expanded on hereafter.

a) The nature of the equipment that is under consideration here is point-to-point and point-to-multipoint equipment where radiation is sectorised and where the sector beamwidth varies from a fraction of a degree up to typically 120° but not exceeding 180°. The design objective is therefore different to that required for a mobile two-way radio or mobile cellular phone base station which generally the objective is to establish omni-directional coverage. The design objective therefore is to minimise interference by establishing sectorial radiation, radially away from the centre of the site, with no radiation across the site, and to the extent possible, no radiation obliquely across the face of other antennas;
b) In the case of a site with a single tower or similar type structure, the requirement is to allocate installation positions on the tower such that best use is made of the legs and the faces of the tower to ensure radiation away from the tower;
c) In the case of a site with more than one tower or similar type structure, the requirement is likewise to ensure that radiation is away from the tower and away from the centre of the site and not across the site in the direction of other towers on the site;
d) In the case of a building, the requirement is to make use of the natural screening properties of the walls of the building by installing equipment on the wall of the building facing the desired direction of coverage, or if on the roof then to install the equipment on a suitable pole or other structure such that radiation is away from the centre of the roof and not across the roof towards the rear face of other antennas;
e) Consideration can also be given to the incorporation of a site synchronisation system between different equipments on a site that are operating on the same frequency or adjacent frequencies.
f) In siting a tower or multiple towers on a high site, consideration should be given to working space for large trucks and mobile cranes, layout space for tilt-up towers and masts, and space for guy rope anchor points for masts;
g) It is essential to give consideration to the siting positions for new shelters, vehicular access to these shelters and to the siting positions for electrical installations in the form of overhead poles, free standing distribution boards, generators and solar panels as well as consideration for the orientation of the latter;
h) Layout of poles;
i) Environmental considerations; and,
j) Health and safety.

3.3.2 EXPANSION

Consideration should be given for the expansion of the site in the future to accommodate increased demand for wireless services and the general growth in the wireless access business.

3.3.3 SITE MAPPING SYSTEM

It is strongly advised to implement some form of geo-spatial mapping system either in 2 dimensions but preferably in 3 dimensions, in which the existing and proposed equipment installations can be mapped. Such a system requires a reference point to be established, such as the corner of a rooftop, in the case of a building high site, and then the position of each installation position to be determined and recorded relative to the reference point. On a tower or mast, each leg and face should be uniquely identified and then the height of each installation position on each leg or face should be determined and recorded.

Installation positions ("Subsites") should be planned in advance to ensure a coherent development and occupation of the subsites rather than allowing a "free-for-all" situation to develop. A well-planned site will enable the operator to maintain the site and installed equipment, to plan future expansions and to assist in the minimisation and resolution of interference issues. In addition, such an orderly approach will greatly enhance the relationship between operators and ICASA during site inspections when operators will be able to confidently and accurately identify their equipment as not being the offending equipment which is being sought out by ICASA in the event of a complaint.

4. SITE CONSTRUCTION

4.1 INTRODUCTION

Site construction involves the establishment of a suitable structure to support antennas and transceivers, a suitable shelter to house in-door equipment, a site electrical power supply, a site earthing system and site lightning protection measures. The design of a site including its structural components and other features should take into account the present and future coverage requirements as well as give adequate attention to various regulatory requirements and health and safety aspects.

Ultimately the wireless performance of a high site is dependent upon the adoption of good site design and construction principles. The risk of mutual interference between systems on a high site or nearby site can be minimised at the design stage. The presence of significant intermodulation, and hence degradation of performance, can be mitigated by a combination of good design and good construction practices.

4.2 SUPPORT STRUCTURES

4.2.1 TYPES OF STRUCTURES

There are various types of structures that can be used to support the outdoor equipment comprising typically of antenna, transceiver and cabling. Possible structures include lattice towers (both steel and carbon fibre), monopoles, masts (guyed towers), small poles and customised structures on which to attach equipment to buildings. The choice of structure is largely determined by the choice of site and the site characteristics. Where the site is essentially a building, then the building, as a high site, can be enhanced with the addition of customised structures, small poles and towers or masts. The choice between a tower or a mast on a building or an open site is based on aspects such as tower loading, wind loading, availability of space for anchor points and budgetary constraints.

Important considerations when selecting, designing and implementing such structures include:

- Fit for purpose
- Structural integrity and rigidity
- Compliance with regulatory requirements
- Safety

Various parameters shall be considered in the selection and design process as poor or inadequate design can be expensive and disruptive to remedy once delivery of service has commenced. The structural integrity of any antenna structure should be established by a competent structural engineer, the analysis of which should include the loads imposed by each wireless system. Future possible requirements should also be taken into account.

4.2.2 TOWER LOADING

For the design of a tower (and similarly for other structures), various parameters need to be specified as detailed hereafter.

a) Tower height: This is determined from coverage requirements and is normally a specific output of propagation predictions that should be carried out. Refer to para **3.2.5 Propagation Considerations**;

b) Equipment to be supported: The equipment to be supported on the tower is determined from service requirements and propagation predictions as discussed above. The equipment to be installed should be described in terms of make, model, basic physical dimensions such as length, breadth, height and mass, worst case flat face area, and any special installation requirements such as the need for sun shields, etc. Allowance should also be made for the physical dimensions and equivalent flat face area of cables and brackets; and,

c) Twist and tilt: the maximum allowable twist and tilt should be specified. The twist and tilt to be experienced by the antenna with the narrowest beamwidth should be no greater than a fraction of the applicable beamwidth.

4.2.3 WIND LOADING

The structural design shall take into account the wind loading of all the components on the structure, e.g. antennas, transceivers and associated cables and brackets. Twist and tilt limitations for parabolic antennas may also have a bearing on design or reinforcement. Parameters to be specified include;

a) Basic wind speed (m/s); and,
b) Mean wind return (years).

4.2.4 SITE CONDITIONS

The following site aspects should be determined and specified:

a) Location in latitude and longitude;
b) Altitude of site above sea level (HASL);
c) Roof height of building above ground level (HAGL);
d) Terrain category;
e) Artificial base height (m); and,
f) Environmental conditions (eg coastal, industrial, etc).

4.2.5 STRUCTURAL INTEGRITY

The selection and/or design of a suitable support structure should be carried out and certified by competent, qualified and registered structural engineers. The same applies to any structural additions or alterations that may be required. Any such work shall be carried out in compliance with national design codes, as applicable, including but not limited to the following:

a) ***SABS 0160 Part 1:1998 Wind design code***, as amended; and,
b) ***SABS 0162 Part 1:1991 Structural code***.

4.2.6 BUILD STANDARDS

Steel structures shall be manufactured in compliance with national codes, as applicable, including but not limited to the following:

a) ***SABS ISO 146:1999 Hot dip galvanising***; and,
b) ***SABS 657-1, SABS 1431 Material standards***.

Due attention shall be paid to the selection and use of other items used in the construction of support structures including but not limited to the following:

c) Use of lock nuts, spring washers and other locking devices; and,
d) Anodising of aluminium components;
e) Use of protective paints;
f) The cutting or drilling of protective coated items;
g) Corrosive aspects in the use of dissimilar metals; and,
h) Products liable to degradation by ultraviolet light should not be used in external situations where there is an acceptable alternative.

The materials which are used in the construction of antennas and their support structures are prone to corrosion. Therefore designers of outdoor installations shall understand the problems which can arise and recognize the practices which have proved adequate to overcome them.

4.2.7 CIVIL AVIATION REGULATIONS

There are regulatory requirements to advise the Commissioner for Civil Aviation of any proposed communications structure, building or other structure. These requirements may impact on the establishment of any proposed structure. Refer to para. **3.2.9 Civil Aviation Regulations** for further details.

4.2.8 ENVIRONMENTAL MANAGEMENT REGULATIONS

There are regulatory requirements regarding specified activities within the scope of the construction, operation and closure/decommissioning of a high site outside of an urban area, may be deemed to be "listed activities" depending upon the details and nature of the target area. Refer to para **3.2.10 Environmental Management Regulations** for further details.

4.2.9 HEALTH AND SAFETY

All design, construction, installation, maintenance and inspection activities shall be carried out with due attention to the various health and safety aspects that apply. Refer to **Section 8 Health and Safety** for further details.

4.3 EQUIPMENT SHELTERS

4.3.1 TYPES OF SHELTERS

There are several types of structures that can be used as shelters, including equipment rooms in large buildings (which function as the high site), containers, prefabricated housings, on-site assembled housings, outdoor cabinets, etc. In many cases, the choice of shelter will largely be determined by the choice of site and the site characteristics. Where the site is essentially a significant building, then a room in the building can be allocated as an equipment room or "shelter". Alternatively, some form of outdoor structure can be assembled or positioned on the roof to act as the shelter. On open sites, a brick and mortar building, container, prefabricated housing, on-site assembled housing, or outdoor cabinet can function as the "shelter". The choice of type of shelter type is based on aspects such as the type and volume of equipment to be accommodated, availability of space and budgetary constraints.

Important considerations when selecting, designing and implementing shelters include:

- Fit for purpose
- Internal volume
- Structural integrity and weather proofing
- Compliance with regulatory requirements
- Safety

The structural integrity of any significant shelter and associated supporting structure (ie building or rooftop) should be established by a competent structural engineer. Future possible requirements should also be taken into account.

4.3.2 DESIGN CONSIDERATIONS

There are several fundamental requirements for equipment shelters which should be given full attention prior to implementation, including the following:

a) The required internal volume should be sufficient for current and anticipated future installed equipment requirements;

b) Requirements to secure the shelter against vandalism and casual attack by intruders should be assessed and well understood. Alarm systems should be provided on sites which warrant a high degree of security;

c) Consideration should be given to ensuring that the equipment shelter is kept at an ambient condition which never allows the temperature to fall below the dew point and which keeps within the specified temperature range of the equipment, or at an acceptable working temperature for personnel. It may be necessary to provide heating, ventilation or cooling to achieve this condition;

d) Lighting, storage and workspace should be provided as appropriate to the type of equipment to be installed on the site;

e) Adequate provision for the ingress of cables for electrical power, earthing, communication cables, wireless interconnection cables from the tower or similar structure should be provided; and,

f) Precautions may be necessary to exclude pests and vermin from the shelter;

4.3.3 SHELTER LAYOUT

The internal layout of the shelter should be based on a number of requirements, identified hereafter.

a) Current and anticipated future requirements for the partitioning of the internal space for individual operators;

b) A separate room, compartment, or dedicated area, close to the door for centralised power distribution, batteries, light switches, air conditioner controls, security systems, etc;

c) Adequate space for and access to equipment cabinets, racks, frames, distribution boards, etc;

d) Requirements for hot/cold passages to meet the air conditioning requirements;

e) Adequate space and facilities for cable trunking purposes, such as false floors and/or overhead cable trays; and,

f) Facilities for access control, remote monitoring and alarms.

4.3.4 SITE CONDITIONS

For the purpose of specifying and/or designing a suitable shelter, the following site aspects should be determined and specified:

a) Location in latitude and longitude;

b) Altitude of site above sea level (HASL);

c) Terrain category;

d) Roof height of building above ground level (HAGL);

e) Structural strength of the rooftop of an existing building, or location of supported points;

f) Vehicular site access details;

g) Rooftop access details; and,

h) Environmental conditions (eg coastal, industrial, etc).

4.3.5 STRUCTURAL INTEGRITY

The selection and/or design of a any structure including a shelter that extends greater than 3m above the building line should be carried out and certified by competent, qualified and registered structural engineers. The same applies to any structural additions or alterations that may be required. Any such work shall be carried out in accordance with the relevant national and local authority design and building codes and regulations, as applicable, including but not limited to the following:

a) ***SABS 0160-1 Part 1:1998 Wind design code***, as amended;

b) ***SABS 0162-1 Part 1:1991 Structural code***; and,

c) ***SANS 10400 National building code***.

4.3.6 BUILD STANDARDS

It should be recognized that corrosion and climatic effects cannot be eliminated. However, the effects can normally be contained by careful design and selection of materials, high quality manufacturing, high standards of installation and a maintenance programme planned for the life of an installation.

Steel structures shall be manufactured in compliance with national codes, as applicable, including but not limited to the following:

a) ***SABS ISO 1461 1999 Hot dip galvanising***; and,

b) ***SABS 657-1 SABS 1431 Material standards***.

Due attention shall be paid to the selection and use of other items used in the construction of shelters including but not limited to the following:

a) Use of lock nuts, spring washers and other locking devices;

b) Anodising of aluminium components;

c) Use of protective paints;

d) The cutting or drilling of protective coated items; and,

e) Corrosive aspects in the use of dissimilar metals.

4.3.7 CIVIL AVIATION REGULATIONS

There are regulatory requirements to advise the Commissioner for Civil Aviation of any proposed communications structure, building or other structure. These requirements may impact on the establishment of any proposed structure. Refer to para. **3.2.9 Civil aviation Regulations** for further details.

4.3.8 ENVIRONMENTAL MANAGEMENT REGULATIONS

There are regulatory requirements regarding specified activities within the scope of the construction, operation and closure/decommissioning of a high site outside of an urban area, that may be deemed to be "listed activities", depending upon the details and nature of the target area. Refer to para **3.2.10 Environmental Management Regulations** for further details.

4.3.9 HEALTH AND SAFETY

All design, construction, installation, maintenance and inspection activities shall be carried out with due attention to the various health and safety aspects that apply. Refer to **Section 8 Health and Safety** for further details.

4.4 ELECTRICAL POWER SUPPLY

4.4.1 TYPES OF ELECTRICAL SUPPLY

High sites can be AC-powered with reticulated power or DC-powered with power provided by on-site diesel generators or alternative forms of energy. Irrespective of the source of electrical power, proper design is required to ensure a reliable supply of electrical power to the wireless equipment and to the safety and security equipment such as navigation warning lights, access control systems, security systems, work space illumination lights, wireless monitoring equipment, etc. The design of the on-site reticulation network should include the necessary earth leakage and over-current protection devices. Any additions or alternations to the electrical installation on a high site shall comply with the requirements of ***SANS 10142-1:2006 The wiring of premises, Part 1: Low-voltage installations***, and shall be carried out and certified by competent registered persons. Adequate provision should be made for immediate power requirements and for future possible requirements.

4.4.2 AC POWER

High sites can be AC-powered with reticulated power provided by Eskom, the local municipality or another licensed power provider. In the case of rural sites, electrical power is usually provided to the high site at 11kV and so provision has to be made for the installation of a step down transformer. Aspects to consider at the design stage include:

a) The cost of an overhead or underground cable installation and 11kV stepdown transformer;

b) The security of such an installation;

c) The location of the transformer such that it is accessible for maintenance without gaining access to the high site itself; and,

d) The transformer earth system shall be connected to the high site earth system.

An AC-powered installation can be supported by a UPS to handle short interruptions in the reticulated AC power.

4.4.3 DC POWER

Alternatively, where AC power is not available or is available but unreliable, high sites can be DC-powered from batteries which are charged from an AC reticulated supply where it is available but unreliable or from diesel generators or from a source of renewable energy such as solar panels, wind-powered generators or fuel cells. Aspects to consider at the design stage include:

a) DC power systems are usually designed for 12, 24 or 48VDC;

b) In coastal areas of South Africa, there is usually sunshine or wind or both but seldom neither;

c) In inland areas of South Africa, there is usually sunshine and irregular wind;

d) Where batteries are used in a cyclic charging mode, the batteries should be dimensioned for a depth of discharge limited to about 20 to 25% in order to obtain a useful life of the batteries of at least three years;

e) Attention should be given to the installation location of wind generators to ensure that performance is not limited by obstructions such as buildings, trees or hills;

f) The design of a solar power system should take into account the insolation for the particular part of the country where the system is to be installed;

g) Attention should be given to the installation location of solar panels to ensure that performance is not limited by obstructions such as buildings, trees or hills. Solar panel arrays should be installed (in the southern hemisphere) facing north but adjusted for any obstructions in order to achieve maximum charging during daylight;

h) The inclination of solar panels to the ground level should be set at an angle of between that of the latitude of the site and latitude + 10°; and,

i) The design of a solar power system for a specific site should take into account the lowest temperature likely to be experienced at that specific site.

4.5 SITE EARTHING SYSTEM

4.5.1 REQUIREMENTS

Site earthing systems are necessary for the safety of personnel and for the protection of equipment. The safety of personnel is at risk due to exposure or potential exposure to high voltages, abnormal conditions relating to equipment, and due to the presence of lightning. The integrity of equipment is at risk due to overvoltage and other abnormal conditions, and due to the presence of lightning. A sound, well-designed and properly maintained site earthing system is the key to the elimination or minimisation of risks to personnel and equipment. Earthing systems shall comply with the requirements of ***SANS 10142-1:2006 The wiring of premises, Part 1: Low-voltage installations***, and shall be carried out and certified by competent registered persons. Where a risk assessment, in accordance with the risk analyses in ***SANS 10313:2012 Protection against lightning – Physical damage to structures and life hazard*** of structures that potentially require lightning protection, in terms of the calculated risk, is higher than the tolerable risk, then protection against lightning is required, in the form of a Lightning Protection System (LPS). Lightning Protection Systems shall be designed and implemented in accordance with the requirements ***SANS 10199:2010 The design and***

installation of earth electrodes and ***SANS 10313:2010 Protection against lightning-Physical damage to structures and life hazard*** in conjunction with ***SANS 62305-1-2-3-4:2011*** and ***IEC 62305-1-2-3-4:2010 Protection against lightning***. Refer to para ***4.6 Site Lightning Protection Measures*** for further details.

4.6 SITE LIGHTNING PROTECTION MEASURES

4.6.1 LIGHTNING EFFECTS AND PROTECTION

Wireless high sites are particularly prone to lightning strikes by virtue of their highly exposed locations and the presence of relatively tall antenna support structures. Various measures should be implemented to protect personnel and equipment from lightning strikes. From an operational perspective, no one should be permitted access to exposed areas of the high site or to climb support structures when there is lightning or an expectation of lightning in the area.

Where a risk assessment, in accordance with the risk analyses in ***SANS 10313:2012 Protection against lightning – Physical damage to structures and life hazard*** of structures that potentially require lightning protection, in terms of the calculated risk, is higher than the tolerable risk, then protection against lightning is required, in the form of a Lightning Protection System (LPS). Lightning Protection Systems shall be designed and implemented in accordance with the requirements ***SANS 10199:2010 The design and installation of earth electrodes*** and ***SANS 10313:2010 Protection against lightning-Physical damage to structures and life hazard*** in conjunction with ***SANS 62305-1-2-3-4:2011 and IEC 62305-1-2-3-4:2010 Protection against lightning.***

4.6.2 LIGHTNING PROTECTION SYSTEMS

The main and most effective measure for the protection of personnel, structures and equipment against injury to or death of personnel or physical damage to structures and equipment is considered to be the Lightning Protection System (LPS). An LPS usually consists of an external and an internal LPS interconnected. A complete system must incorporate both an external and an internal LPS. An external LPS is intended to:

- Intercept a lightning flash to the structure;
- Conduct lightning current safely towards earth; and,
- Disperse lightning current into the earth.

An internal LPS is intended to:

- Prevent dangerous sparking within the structure or shelter using either equipotential bonding or a separation distance between the external LPS and other electrically conducting elements internal to the structure or shelter.

The design of an LPS is complex and requires specialist knowledge and skills. LPS and earthing specialists should be consulted.

Some keypoints regarding lighting protection and earthing include the following:

a) A lightning finial may be required to extend the zone of protection to protect equipment mounted on top of the structure. The finial should extend to at least 1m above the highest equipment;

b) All antenna feeders should be bonded to the tower at the upper and lower ends and earthed at the point of entry into the equipment shelter;

c) All equipment both indoor and outdoor, including antennas, shall be earthed with individual earthing connections. Daisy-chaining of earthing connections shall not be permitted;

d) All Lighting Protection Units (LPU) shall be earthed at the point of entry into the equipment shelter;

e) The shape and dimensions of a lightning protection earthing system are important when dealing with safe dispersion of the lightning current into the ground;

f) In order to minimise any dangerous overvoltages, a low resistance earthing system is recommended, preferably less than 10 Ohms; and,

g) A single integrated earthing system on a site is preferable which is suitable for both a lightning protection system and for a safety earthing system. The resistance should then be less than 1 Ohm.

4.6.3 GALVANIC ISOLATION

Where a wireless system on a rooftop or adjacent to the shelter on a high site is integrated with a high value indoor system such as a local area network, public network, data centre, etc then serious consideration should be given to implementing galvanic isolation between the outdoor equipment and the indoor equipment. This will involve the use of an optical fibre connection between the outdoor equipment and the indoor equipment in order to avoid lightning induced surges from damaging or destroying high value indoor equipment. At the same time, special attention should be given to avoiding lightning induced surges from flowing on power cables between the outdoor equipment and the indoor equipment.

5. EQUIPMENT INSTALLATION

5.1 INTRODUCTION

In provisioning wireless access services to their clients, operators employ wireless access equipment to provide connectivity between the premises of clients and high sites in both point-to-point and point-to-multipoint configurations. Wireless backhaul equipment is employed to provide backhaul services between these high sites and various other points of presence, usually in a point-to-point (P-to-P) configuration but use can also be made of a point-to-multipoint (P-to-MP) configuration for backhaul. P-to-P and P-to-MP applications can be implemented in the following frequency bands:

Point to Multipoint Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands (TV bands).

Point to Point Applications

- Licence-exempt bands: typically 2.4GHz and 5GHz (ISM bands), and possibly in the future, the 700 and 800MHz bands (TV bands).
- Licensed bands: typically 6 to 38GHz bands (ITU bands).

The various system types, in terms of relationships between applications, bands, equipment configurations and regulatory details, are tabulated here:

Table 1: System Types

<table>
<tr><th>APPLICATION</th><th>DESCRIPTION</th><th>BAND</th><th>REGULATION</th><th>CONFIGURATION</th></tr>
<tr><td>P-to-P</td><td>ISM 2.4 (Bridge Mode)</td><td>2.4GHz</td><td>Licence-exempt</td><td rowspan="2">Antenna/transceiver configurations can be one of two types:
• Connectorised (separate antenna connected via coaxial cable)
• Attached (clip-on or bolted –on)</td></tr>
<tr><td>P-to-P</td><td>ISM 5.x (Bridge Mode)</td><td>5GHz</td><td>Licence-exempt</td></tr>
<tr><td rowspan="2">P-to-P</td><td rowspan="2">Conventional microwave link</td><td rowspan="2">17/24GHz</td><td rowspan="2">Licence-exempt</td><td>Indoor-Outdoor (attached antenna)</td></tr>
<tr><td>All Outdoor (attached antenna)</td></tr>
<tr><td rowspan="4">P-to-P</td><td rowspan="4">Conventional microwave link</td><td rowspan="4">6GHz to 38GHz bands</td><td rowspan="4">Licensed</td><td>Indoor-Outdoor (attached antenna)</td></tr>
<tr><td>All Outdoor (attached antenna)</td></tr>
<tr><td>All Outdoor (built-in antenna)</td></tr>
<tr><td>Indoor-Outdoor (built-in antenna)</td></tr>
<tr><td>P-to-MP</td><td>ISM 2.4 (Access Point Mode)</td><td>2.4GHz</td><td rowspan="2">Licence-exempt</td><td rowspan="2">Antenna/transceiver configurations can be one of two types;
• Connectorised (separate antennas connected via coaxial cable)
• Integrated (antenna built-into transceiver</td></tr>
<tr><td>P-to-MP</td><td>ISM 5.x (Access Point Mode)</td><td>5GHz</td></tr>
<tr><td colspan="5">Continued overleaf</td></tr>
</table>

P-to-MP	TV White Spaces	700MHz/ 800MHz	Uncertain but expected to be licence-exempt	External antenna
P-to-MP	Digital Dividend 1	800MHz	Not available until digital migration completed. Most likely to be licensed due to high costs of migration	External antenna
P-to-MP	Digital Dividend 2	700MHz	Uncertain future. Will be clarified in 2015. Most likely to be licensed if implemented	External antenna

Wireless equipment for these applications is built to standards that have been created to ensure the efficient use of the radio spectrum. These standards specify appropriate performance parameters for transmitters, receivers and antennas. Good installation design will ensure that as far as possible the performance of a complete installation will preserve the performance characteristics of the components, result in the intended field strength in the designated area, and avoid co-channel and adjacent channel interference.

5.2 EQUIPMENT TYPES

5.2.1 POINT-TO-POINT APPLICATIONS

Equipment used by operators for point-to-point applications is generally either equipment designed in accordance with the ***IEEE 802.11*** set of standards for licence-exempt, or in accordance with ITU-R requirements for licensed use. Licence-exempt operation is implemented in the 2.4GHz band (2400 to 2483.5MHz), the 5.8GHz band (5470 to 5725MHz and 5725 to 5875MHz), the 17GHz band (17.1 to 17.3GHz), and the 24GHz band (24.00 to 24.25GHz).

Equipment operating in the 2.4GHz band should conform to the ***IEEE 802.11g or n*** standard and equipment operating in the 5GHz band should conform to the ***IEEE 802.11a or n*** standard, in order to get the benefit of OFDM multiplexing through the elimination of intercarrier and intersymbol interferences, resulting in higher throughputs.

Licensed bands exist from 6 to 38GHz and include the 6, 7, 8, 11, 13, 15, 18, 23 and 38GHz bands. Even higher frequency bands are available.

Refer to the following ICASA published documents for details regarding output power and other limitations in the use of these frequencies:

- ***Government Gazette No. 32769, dated 2 December 2009, Notice 1597 of 2009***;
- ***Government Gazette No. 34172, dated 31 March 2011, Notice 184 of 2011***; and,
- ***Government Gazette No. 36336, dated 28 June 2013, Notice 354 of 2013***.

5.2.2 POINT-TO-MULTIPOINT APPLICATIONS

Equipment that is primarily used for point-to-multipoint applications is equipment designed in accordance with the IEEE 802.11 set of standards for licence-exempt operation. This equipment is used in the 2.4GHz band (2400 to 2483.5MHz), the 5.8GHz band (5470 to 5725MHz and 5725 to 5875MHz).

As with point-to-point operations, equipment operating in the 2.4GHz band should conform to the IEEE 802.11g or n standard and equipment operating in the 5GHz band should conform to the IEEE 802.11a or n standard, in order to get the benefit of OFDM multiplexing through the elimination of intercarrier and intersymbol interferences, resulting in higher throughputs.

Refer to the above referenced documents for further details regarding output power and other limitations in the use of these frequencies.

5.2.3 USE OF TV BANDS

The use of TV bands, in terms of TV white spaces and Digital Dividends 1 and 2 is under trial and discussion. None of these three opportunities is likely materialise until new standards are approved, analogue to digital TV migration has taken place including analogue switch-off, and the next ITU World Radio conference, WRC15 has taken place in 2015.

5.2.4 EQUIPMENT INSTALLATION

Some keypoints regarding the installation of equipment include the following:

a) All equipment both indoor and outdoor, including antennas, shall be earthed with individual earthing connections.

b) Daisy-chaining of earthing connections shall not be permitted;

c) All Lighting Protection Units (LPU) shall be earthed at the point of entry into the equipment shelter;

d) Consideration should e given to the installation of a synchronization system in order to minimise interference between radio systems installed on a particular site.

5.3 ANTENNAS

5.3.1 ANTENNA CHOICE

Parabolic reflector and panel antennas are the primary choice of antenna for use with the equipment described above. The typical antennas used are tabulated below per type and configuration of equipment:

Table 2: Antenna Requirements

APPLICATION	DESCRIPTION	BAND	CONFIGURATION	EXTERNAL ANTENNA TYPES
P-to-P	ISM 2.4 (Bridge mode)	2.4GHz	Antenna/transceiver configurations can be one of three types: • Connectorised (separate antenna connected via coaxial cable) • Attached (clip-on or bolted –on)	• Solid parabolic reflector (linear or cross polarised) • Grid parabolic reflector (linear or cross polarised)
P-to-P	ISM 5GHz (Bridge Mode)	5GHz		
P-to-P	Conventional microwave link	17/24 GHz	Indoor-Outdoor (attached antenna)	• Solid parabolic reflector
			All Outdoor (attached antenna)	
P-to-P	Conventional microwave link	6GHz to 38GHz bands	Indoor-Outdoor (attached antenna)	• Solid parabolic reflector
			All Outdoor (attached antenna)	
			All Outdoor (built-in antenna)	
			Indoor-Outdoor (built-in antenna)	
P-to-MP	ISM 2.4GHz (Access Point Mode)	2.4GHz	Antenna/transceiver configurations can be one of two types; • Connectorised (separate antennas connected via coaxial cable) • Integrated (antenna built-into transceiver	At AP end: • Panel (single or multiple) At Client end: • Panel • Solid parabolic reflector • Grid parabolic reflector
P-to-MP	ISM 5GHz (Access Point Mode)	5GHz	Antenna/transceiver configurations can be one of two types; • Connectorised (separate antennas connected via coaxial cable) • Integrated (antenna built-into transceiver	At AP end: • Panel (single or multiple) At Client end: • Panel • Solid parabolic reflector • Grid parabolic reflector

P-to-MP	TV White Spaces	700MHz/ 800MHz	External antenna	• Yagi • LPDA
P-to-MP	Digital Dividend 1	800MHz		
P-to-MP	Digital Dividend 2	700MHz		

At microwave frequencies, solid parabolic reflector antennas have the highest gain and the narrowest beamwidth, followed by grid parabolic antennas. Panel antennas exhibit wide beamwidths with moderate gain. In the UHF band, Yagi antennas have high gain but relatively narrow frequency bandwidth, whereas log periodic dipole arrays (LPDA) have wide bandwidth but relatively lower gain than Yagi antennas. Cross polarisation can be employed to minimise co-channel interference or to increase the capacity of a link.

To assist in minimising interference on a high site, omnidirectional antennas should never be used as these cause interference to other systems in all directions and are themselves a receptor to interference all round, from other systems. Also by not using omnidirectional antennas, the possibility of intermodulation distortion is greatly reduced. If omnidirectional coverage around a high site is required, then the desired coverage area should be divided into sectors and sector antennas used.

All of the services referred to in the tables above have a regulated power limitation. This is usually defined in terms of the effective isotropic radiated power (EIRP), measured in dBi. EIRP is the product of the antenna gain and the output power of the transmitter. Therefore the highest practical antenna gain should be used with the lowest practical output power.

Gain is a trade-off with beamwidth. In P-to-P applications, the narrower the beamwidth, the less will be the impact of multipathing, and hence the less the impact on throughput. High gain can be achieved with parabolic reflector antennas, more so with solid reflectors than with grid reflectors. In P-to-MP applications, the minimum possible beamwidth will be determined from the sector coverage requirements. Hence the highest possible gain for a given sector beamwidth is required. This is usually achieved with panel antennas where gain can be increased by the addition of additional patch antennas, for a fixed beamwidth.

5.3.2 ANTENNA SITING

Antennas should be installed at heights determined by propagation analysis, also taking into account Fresnel zone clearance. On site, antennas should be installed as close to the edge of the site, pointing away from the centre of the site or tower. If omnidirectional coverage or wide coverage (wider than one sector can accommodate) is required, then multiple sectors should be utilised, also mounted at the edge of the site and pointing away from the centre of the site. Antennas should be installed as orthogonal to the edge of the site as practical with the sector antennas placed as far apart as possible, preferably at the edge of the high site and pointing away from the centre of the site or centre of the tower. No radiation across a site that nullifies the potential use of another installation location on that site should be allowed.

When determining the mounting positions for antennas each antenna should be mounted in a manner which does not impair its performance. Antennas should be installed with adequate attention to spacing between antennas and between antennas and adjacent parapet walls, buildings and other structures in order to avoid interfering reflections. A minimum spacing of between 2 and 3m should be considered. Antennas should also be positioned in order to avoid mutual interference through radiation from both the mainbeams and sidelobes. As a general rule, the less directional the radiation pattern of an antenna, the greater the influence the mounting environment has on the pattern. Highly directional antennas such as parabolic dishes and antennas with large mesh reflectors have high front/back ratio and may be regarded as largely independent of what lies behind them. Antennas of moderate front/back ratio such as Yagi antennas must be mounted with their rear elements at least one wavelength from the supporting tower if optimum performance is to be achieved.

5.3.3 ANTENNA SPECIFICATION

The following parameters, as applicable, should be specified when procuring or selecting antennas.

a) Band: Identify the band of interest in MHz or GHz;

b) Frequency: Specify the centre frequency or the frequency range of interest in MHz;

c) Gain: Specify in dB relative to an isotropic radiator in dBi;

d) VSWR: Specify the maximum allowable VSWR over the frequency range of interest;

e) Beamwidth: Specify the beamwidth in the azimuth and elevation planes, together with any necessary restrictions on side or rear lobe levels;

f) Downtilt: Specify the amount of electrical downtilt required, and whether fixed or adjustable;

g) Front to back ratio: Specify the minimum allowable front to back ratio in dB;

h) Input impedance: Specify the nominal input impedance in Ohms;

i) Polarisation: Specify linear or cross-polarisation and the orientation required;

j) Isolation: With cross-polarisation, specify the isolation in dB;

k) Input power: Specify the required power handling capability in Watts;

l) Connector: Specify the type and sex of the connector to be fitted to the antenna;

m) Fly-lead: If required, specify the length of the fly-lead to be fitted in metres and the cable type and cable connector;

n) Survival wind speed: Specify the maximum wind speed that the antenna shall be capable of surviving;

o) Temperature range: Specify the temperature range to be experienced by the antenna in °C, paying particular attention to the requirements for installations to be established in areas that experience extreme variations in temperature;

p) Mounting arrangement: Specify the required type of mounting and adjustment arrangements; and,

q) Radome: The inclusion of a radome for a solid parabolic reflector antenna should be considered where such an antenna is to be used in an area of high wind, in order to minimise the effective twist and tilt.

r) Earthing: An earthing lug shall be provided on the antenna to enable the antenna to be securely earthed.

5.4 CABLING

5.4.1 GENERAL

Various types of cabled connections are required on a high site including for power (both AC and DC, high voltage and low voltage), earthing, radio frequency, intermediate frequency, data and specialised applications such as access control and security systems. Only high quality types of cables, cable connectors, terminations, etc should be used. Screened and armoured cables should be used wherever appropriate and exposed cables should be UV-rated. The various types of cables and connectors used on a high site should be kept to a minimum.

5.4.2 CONNECTORS

In the selection of connectors, the following precautions should be taken:

a) Connectors used for RF and IF connections should be of high quality and limited to N-type, F-type, SMA, TNC and DIN7/16. The use of such connectors produces maximum screening effect and provides the best RF connection between the various components of the system;

b) For cabled connections using the RJ45 connector, only metal body cable-end connectors should be used; and,

c) All connectors must be fitted in conformity with manufacturers' instructions to ensure proper sealing and electrical uniformity and should be tightened to the manufacturer's recommended torque settings.

5.4.3 CABLES, CABLE ROUTES

In the selection of cables and cable routes, the following precautions should be taken:

a) For RF and IF connections and wherever possible, solid, semi-rigid or double-screened cables should be used. This is to ensure maximum screening between adjacent RF, IF, data and power cables and to reduce coupling between equipment;

b) The direct and shortest route is always the best for minimum radiation and minimum insertion loss;

c) Data connections should be made using only screened twisted pair cable;

d) Surge suppressors and earthing clamps should be fitted to RF, IF data and power cables, as per manufacturers recommendations. All such devices should be connected via the shortest path to a common site earthing system;

e) Earthing cable for individual units should be typically 16mm^2 yellow/green earthing cable.

f) All cables entering a shelter should be installed via a common metallic bulkhead which should be earthed to the site earthing system. All such cables should pass through surge arrestors fitted to the bulkhead;

g) All cables should be installed in metallic cable trays which should be well-earthed;

h) All cables should be strapped neatly to cable trays and structures at regular interval using metallic cable clamps or UV-rated cable ties;

i) Provision for drip loops should be made where cables connect to outdoor equipment;

j) Care should be taken with all joints or connections with dissimilar metals, as these can become a source of corrosion;

k) Additional attention is required for sites where extreme weather conditions are possible. The presence of snow and ice can affect wireless performance and result in physical distortion of metallic antenna components. Extremely low temperatures can result in fractures in materials, leading to moisture ingress resulting in permanent damage;

l) On completion of cable installation, all external connectors and earthing connectors should be suitably sealed or protected against the ingress of moisture using self-amalgamating tape or other suitable moisture-proof solutions; and,

m) All cables, connectors, cable trays, cable clamps, earthing clamps, surge arrestors, etc should be securely fixed in order to protect the installation from damage due to vibration throughout the projected life of the installation.

5.4.4 CABLE IDENTIFICATION, TERMINATIONS AND EARTHING

Feeder cables should be uniquely and permanently identified at least at each end and at the point of exit from the shelter. More frequent identification is advisable where the identification of cables is made difficult, for example where cables pass through a duct.

6. MAINTENANCE

6.1 INTRODUCTION

Maintenance takes the form of corrective maintenance and preventive maintenance. Corrective maintenance relates to maintenance actions of a repair nature where actions are taken to return a system back to normal working conditions as soon as possible after a fault has occurred and service performance is affected or threatened. The ability to restore a service to required performance levels is a measure of the maintainability of the high site and its systems and is impacted by the degree of attention given to the matter during the design phase and by the degree of preventive maintenance that is carried out. Preventive maintenance should be carried out on a regular basis and to the level that is relevant for the various components of a high site implementation.

A site logbook should be established for each high site in which observations and actions are recorded during each visit to the site.

6.2 GENERAL HIGH SITE MAINTENANCE

Apart from regular maintenance on high site components, which is discussed in detail below, regular maintenance on the high site itself should be planned and carried out on a regular basis. This should include the following:

a) The high site area should be inspected at least once or twice a month, depending on the locality and criticality of the site, for any signs of degradation of the high site including illegal intrusion, malicious damage, theft, damage by pests and vermin, overgrown vegetation, other risks of fire, poor work practices by other installers and maintainers, littering, soil erosion, etc;

b) Access roads should be inspected every quarter for indications of soil erosion, bad weathering of roads, rocks or other obstacles on the roads, any developments, illegal or unapproved activities that may affect access to the high site, etc;

c) Any facilities on site such as toilets, drinking water, fire extinguishers should be inspected and returned to the appropriate level of service;

d) Recording of any of these issues; and,

e) Action to overcome or remove or halt any of the issues identified above.

6.3 SUPPORT STRUCTURES

Support structures such as towers, masts and custom-design structures should be thoroughly inspected at least once a year by staff trained and qualified to climb such structures. Other staff can be instructed to inspect more easily accessed areas such as tower footings and mast guy rope anchor points. Inspections should address the following:

a) General condition of structures;

b) Presence of rust or corrosion;

c) Guy rope tension;

d) Presence of any loose items including nuts, bolts, locking devices, cabling, cable trays, antennas, etc;

e) Recording of any of these shortcomings;

f) Adjustment of guy rope tensioners;

g) Greasing of guy rope tensioners; and,

h) Identification, removal and surface treatment of any areas of corrosion;

6.4 EQUIPMENT SHELTERS

Equipment shelters should be thoroughly inspected externally every quarter and internally at least once or twice a month. Inspections should address the following:

a) Any external damage, deterioration, corrosion to the shelters;

b) Repairs to any damage, remediation of any deterioration and removal of any corrosion;

c) General tidiness inside and outside the shelters;

d) Clutter resulting from recent repairs, modifications, installations;

e) Service levels and testing of access control systems, security systems and monitoring systems;

f) Servicing of fire extinguishers;

g) Removal of discarded materials, packaging, excess cables, faulty equipment, etc; and,

h) Stock levels of spares held on site.

6.5 ELECTRICAL POWER SUPPLY

With regard to the high site electrical power supply, the following actions should be carried out:

a) Reticulated power supply installations should be inspected annually for any signs of damage or deterioration, particularly where high sites are in remote rural areas;

b) Voltages should be checked on a regular basis;

c) Any signs of hot spots in distribution boards or cabling should be noted and reported;

d) Earth leakage protection devices should be tested once a year (with alternative power activated);

e) Standby generators should be started at least once a month and run sufficiently to restore charge to the starting battery;

f) The automatic starting and loading testing of standby generators should be carried out once a quarter;

g) Mechanical maintenance on standby generators should take place as specified by the manufacturer;

h) The automatic switchover and load testing of UPS's should be carried once a quarter;

i) UPS batteries should be individually tested once a year;

j) In dry hot climates, solar panels tend to accumulate much dust and therefore should be cleaned on a regular basis, preferably during every site visit, depending upon the availability of water; and,

k) Solar batteries should be individually tested once a year.

6.6 SITE EARTHING SYSTEM

The earthing system should be checked once a year to ensure that it is still intact and that the earth impedance has not risen to an unreasonable figure.

6.7 SITE LIGHTNING PROTECTION MEASURES

Once a year all earthing points and earth straps should be inspected for damage, arcing or corrosion and any such damage made good. Immediately after damage has resulted on a high site due to lightning discharges, all the lightning measures, in terms of earthing points, earth straps and surge protection devices should be inspected and repaired or made good.

6.8 EQUIPMENT, ANTENNA AND CABLING

With regard to the equipment installed on a high site, the following actions should be carried out:

a) All wireless equipment, antennas and cabling installed outdoors should be thoroughly inspected once a year for signs of damage, deterioration, corrosion or UV-caused damage;

b) All items should be checked for tightness and tightened where necessary;

c) All forms of protection against moisture ingress, such as self-amalgamating tape should be inspected and replaced if necessary;

d) All indoor equipment should be thoroughly inspected once a year for signs of damage, deterioration or corrosion; and,

e) Equipment performance figures obtainable from element management systems or other types of built-in test and monitoring equipment should be evaluated for any signs of deterioration in performance of the equipment.

7. SITE ADMINSTRATION

7.1 INTRODUCTION

The success of a high site, particularly one that is made use of by several operators, is dependent upon efficient administration of the high site in terms of implementation of security measures, site access control, site maintenance, site tidiness, record keeping, change control, maintenance of technical standards, and preparation for site inspections.

7.2 SITE SECURITY AND ACCESS CONTROL

Suitable forms of perimeter security should be established in order to prevent actions such as theft or malicious damage to high site infrastructure and installed equipment. At the same time, suitable access control systems need to be installed and maintained to enable authorised access to take place without adversely impacting site security. In is in the interests of all operators on a site to cooperate in the operation of such access control systems.

7.3 SITE MAINTENANCE

It is important to the success of a high site that regular maintenance is carried out on a high site. All operators making use of a high site should prepare and undertake scheduled maintenance on their installations on the site.

7.4 SITE TIDINESS

It is in the interests of all parties, and to some degree a legal requirement in terms of environmental management legislation, to establish a tidy work ethic on high sites. All operators should at all times keep their work area in a neat, clean and safe condition, and remove from the premises and in the vicinity thereof and properly dispose of all debris, discarded materials and rubbish caused by their work on high sites.

7.5 RECORD KEEPING

The efficient administration of wireless sites relies on precise details of operators and their installations on a site. Contact details of all operators (and their maintenance contractors) making use of a site should be made available and displayed in a weatherproof form in a convenient location on the site. Technical details of all equipment installed should be made available and also displayed for the benefit of other operators. Such details should include:

a) Type of service;

b) Approximate location of equipment on the site an or on specified towers, masts or other structures;

c) RF band utilised;

d) Frequencies/channels utilised; and,

e) EIRP of each transmitter.

7.6 CHANGE CONTROL

Operators should ensure that all proposed on-site changes are appropriately and accurately documented in the relevant forms and/or formats and submitted to the relevant authorities. This applies, but is not limited, to proposed changes in installed equipment, operating parameters, services operated, structural and electrical changes, and changes which affect health and safety and the environment.

7.7 MAINTENANCE OF TECHNICAL STANDARDS

All operators making use of a high site should be encouraged and supported in maintaining a high level technical standards and integrity.

7.8 SITE INSPECTIONS

As a consequence to complaints of interference, ICASA may wish to carry out high site inspections in order to identify and possibly prosecute operators that are proven to be the cause of the interference. Operators are encouraged to cooperate with these inspections, and in preparation for such inspections, operators should ensure that:

a) Equipment is in proper working order and operating fully within the limits as determined by ICASA;

b) Equipment is fully labelled in terms of type-approvals, operator's name, and contact details;

c) Subsites are safe, neat, clean and free of debris, discarded materials and rubbish;

d) Documentation detailing type and details of the equipment installed is up to date; and,

e) During site inspections, operators have copies of all their applicable licences in hand.

8. HEALTH AND SAFETY

8.1 INTRODUCTION

The safety of the working environment on, and in the vicinity of high sites should always remain a consideration of high importance to all operators. All operators on a high site have a legal obligation to ensure that all activities carried out on a high site by its staff and contractors, are carried out in accordance with the conditions of the ***Occupational Health and Safety Act No. 85 of 1993*** as amended by the Occupational Health and Safety Amendment Act No. 181 of 1993. In addition, it is in the operator's interests to ensure that it complies with the ***Compensation for Occupational Injuries and Diseases Act 130 of 1993*** as amended and as applicable.

8.2 ON-SITE CONSIDERATIONS

In most cases common sense is the best guide to the physical safety on high sites. Operations on site must follow safe working practices and procedures. A working policy stipulating risk management strategies should therefore be enforced for all works, safeguarding the health and safety of staff, especially those engaged on work external to the equipment shelter and at height.

As part of the process of avoiding incidents on site, all operators on site should take steps to ensure that all their visitors and staff working on site wear the necessary personal protective equipment that mitigates or reduces exposure to identified hazards and risks to below set mandatory levels. In accordance with the requirements of the ***Construction Regulations, 2014***, only competent and medically declared fit staff shall be allowed to climb support structures. They should have had practical training on all aspects of fall arrest and rope access, including the emergency procedures pertaining to these activities in compliance with the requirements of ***SANS 10333-1:2006 Industrial Rope Access, Part 1: Worksite procedures, and Part 3: Inspection, certification and management procedures for equipment***. Only one operator or contractor may work on a structure at a time. Arrangements for lifting equipment past working installations should be coordinated.

No one should be permitted access to exposed areas of the high site or to climb support structures when there is lightning or extreme meteorological conditions or the expectation of either condition in the area.

A consideration that is sometimes overlooked is the danger of falling ice in colder climates during winter months. The structure design and site layout should take into account the icing which could reasonably be expected to occur on structures and antennas in a particular location and the danger of falling ice in relation to staff and damage to shelters, equipment, antennas and feeders.

The inside of the equipment shelter is defined as a confined space according to the ***Occupational Health and Safety Act No. 85 of 1993***, therefore care should be taken to ensure that sharp projections are avoided and that the common walkways remain clear and unhindered. This is particularly important when additional services are added and equipment shelters become crowded. Where lead acid battery power supplies are installed the first aid aspect of acid splashes must be considered and in particular the requirement for eye wash solution in first aid cabinets. Where soldering irons are in use care should be taken such that hot irons are not left unprotected, but are placed in suitable holders.

8.3 ELECTRICAL SAFETY

Accidents that are related to the electrical installation are amongst the most common occurrences. The design and construction of the electrical installation on a high site shall comply with the requirements of ***SANS 10142-1:2006 The wiring of premises, Part 1: Low-voltage installations***, and shall be carried out and certified by competent registered persons.

It is desirable that anyone who regularly works in a wireless site environment should be aware of the procedures for the first aid treatment of persons suffering electric shock.

8.4 FIRE HAZARDS

The requirements for the prevention and extinguishing of fires are governed by legislation. In particular the storage of paper, cardboard boxes, paint and other flammable goods is not desirable. The number and type of extinguishers that are required at a site should be decided on in consultation with the appropriate fire authority.

8.5 EXPOSURE TO NON-IONISING RADIATION

By the very nature of the business of providing wireless-based services, non-ionising radiation is present on high sites. Whilst the levels of radiation on a high site are expected to be relatively low, all operators on site have the responsibility to ensure that care shall be taken to avoid any inadvertent exposure to non-ionising radiation above both public- and occupational thresholds as defined and published from time to time by the Department of Health and the International Commission on Non-ionizing Radiation Protection (ICNIRP), by being in close proximity of antennas. The ***ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz) 1998,*** and subsequent relevant statements and publications, can be consulted for further guidance.

Consideration should be given to the issuing of personal EMF monitors to all staff and contractors performing commissioning and maintenance work in front of energised antennas. Consideration should also be given to the inclusion of lock-out procedures.

8.6 SYMBOLIC SIGNS

Symbolic safety signs shall be attached to and be visible on high sites. The signs shall comply with the legal requirements. The standard ***SANS 1186-1 Symbolic safety signs – Part 1; Standard signs and general requirements*** can be referenced for more information on symbolic signs

9. APPENDICES

9.1 APPENDIX A: ABBREVIATIONS

AC	Alternating Current
AP	Access Point
°C	Degrees Centigrade
CW	Continuous Wave
dB	deciBel
dBi	deciBel isotropic
DC	Direct Current
EIRP	Effective Isotropic Radiated Power
EMC	Electro-Magnetic Compatibility
ETSI	European Technical Standards Institute
GHz	GigaHertz
HAGL	Height Above Ground Level
HASL	Height Above Sea Level
ICASA	Independent Communications Authority of South Africa
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ISM	Industrial, Scientific and Medical
ITU	International Telecommunications Union
kV	kilovolt
LPDA	Log Periodic Dipole Array
LPS	Lightning Protection System
LPU	Lightning Protection Unit
m	Metres
MHz	MegaHertz
m/s	metres per second
NEMA	National Environmental Management Act
OFDM	Orthogonal Frequency Division Multiplex
P-to-MP	Point to MultiPoint
P-to-P	Point to Point
SABS	South African Bureau of Standards
SACAA	South African Civil Aviation Authority

SANS	South African National Standards
TV	TeleVision
UHF	Ultra High Frequency
UPS	Uninterruptible Power Supply
UV	Ultra Violet
VDC	Volts Direct Current
VSWR	Voltage Standing Wave Ratio
WAPA	Wireless Access Providers Association
WRC	World Radio Conference