Masters of Science in Engineering.

UPGRADED ANTENNAS FOR 5G ANTENNA ARRAY CELLULAR BASE STATION ON KALISIMBI VOLCANO IN RWANDA

***Done* by:**

Winfred INGABIRE **Student number: 1490760**

Supervised by: Prof. Steve Maher
Edmond, Oklahoma.
USA, August 2014.

APPROVAL

This is to certify that the project work entitled "**UPGRADED ANTENNAS FOR 5G ANTENNA ARRAY CELLULAR BASE STATION ON KALISIMBI VOLCANO IN RWANDA**" is a record of the original work done by INGABIRE Winfred (Student ID number: 1490760) in partial fulfillment of the requirement for the award of a Master's Degree in Electrical and Computer Engineering at Oklahoma Christian University in the academic year 2014

Winfred INGABIRE

ID number: 1490760

Prof. Steve MAHER

Project Supervisor

ACKNOWLEDGEMENT

I would like to take this opportunity to dedicate this project to the Almighty God to whom we owe everything, my dear husband Gerald and my daughter Isheja. I appreciate my professor Steve Maher and Oklahoma Christian administration, for all their unceasing help. I also thank my family, friends and everyone who has helped me along the way.

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1. OVERVIEW

One of the most important components in wireless and cellular communication systems, that is mostly taken-for-granted while upgrading technologies, is Antennas. However they are critical to the operation of a cellular base station for wireless and cellular communication systems. Whereby there has to be many choices available depending upon the particular site and operating environment.

Development of essentially new base station antennas is my interest as mobile communication systems are continuing to grow rapidly, particularly in Rwanda. The new millennium has seen the introduction of fifth-generation (5G) mobile communications systems that will offer broadband data services with high data bit rates, enhanced multimedia services and Internet applications.

As wireless communication markets develop very rapidly, with it, the number of base station antennas has also increased. In coming years, the new generation of wireless communication systems will demand new and improved base station antennas. New base station antennas will need to be developed that will replace current sector panel antennas and reduce the overall number of antennas on cellular base stations.
My project is to provide an overview on fifth-generation mobile communication systems and conformal antennas that could be used in such systems in Rwanda on Kalisimbi volcano. It also aims at analyzing the effects of curvature on the performance of cylindrical microstrip antennas and the operating frequency band for the main fifth-generation air interface. The effects of curvature will be analyzed using High Frequency Structure Simulator (HFSS) software which considers mutual coupling effects in antennas. This project aims at establishing a conformal array on Kalisimbi volcano for the above services to be able to be rendered and applications to be applied in Rwanda and in the region; it will be a new designed base station antenna array with upgraded antennas with improved characteristics or behavior.

Kalisimbi is the highest volcano in Rwanda with the highest altitude in Rwanda of 4507 meters; it is an appropriate place for Rwanda to have a central conformal cellular base station which will serve in the forthcoming 5G technology. Its geographical area is very good to provide this service with no problem.

Hence this project aims at;

- Designing a proposed new array of antennas that will provide a stronger signal for the intended 5G applications to be applied in Rwanda.
- Using a new antenna that overcomes the deficiencies of most classical and less-than-optimum performing antennas that are widely used today in Rwanda.

- Designing the antenna that matches with the 5G technology in Rwanda, which has the specific 5G specialties contrast to current generations

2. INTRODUCTION TO THE RWANDAN GOVERNMENT'S VISION, THE STRONG SUPPORT TO THIS PROJECT.

"….Access to ICT is no longer a privilege but a basic right for all Citizens..." H.E. PRESIDENT PAUL KAGAME. Rwanda has long launched what is called the 2020 Vision, where a stable economy is envisioned and a well-developed infrastructure will be in place. One of the factors that are on the fore-front of our nation achieving this goal, is the ICT infrastructure, The International Telecommunication Union (ITU) set up by the UN is committed to ensure that the benefits of new technologies, especially ICTs, are available to all. Access to information, and thereby to the creation of knowledge, is considered a critical factor in the development process. This requires an adequate range of ICT networks and services. On the other hand, it implies the ability to use those tools to develop applications that benefit society (learning by doing). But both the tools and the ability to use them are unevenly distributed. In a bid to respond to the Millennium Development goals set in place by the United Nations, the Government of Rwanda has invested a lot of money in the construction of a nation-wide fiber optic infrastructure. For this to be achieved, an optimum exploitation of this network has been planned. The main Construction of the National Backbone (NBB) has been that of a high-speed Fiber Optic Cable Network (2,300 Km) to interconnect more than 230 government sites in the country and border posts (Uganda, Tanzania, Burundi, DRC). In this regard therefore, Kalisimbi being the tallest volcano, found in the Northern part of Rwanda, is the best place to put an appropriate Antenna base station capable to serve in the country as well as the region.

3. BACKGROUND AND APPLICABLE DOCUMENTS

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Establishing a base station in any place in the world has restrictions and regulations that must be followed for the project to be implemented. For this particular project however, there has to be land proprietary documents from the government of Rwanda, particularly from Musaze district where this Volcano is located. There has to be also documents submitted to the ministry of Environmental preservations, showing how the project is environmental conservative and does not affect the population negatively, this in return leads to the provision of a confirming project implementation certificate. The base station design should also be of allowed quality standards as shown by the experts in International Electrical and Electronics Engineers (IEE), International Telecommunication Union (ITU), and so on. There are also other organs in Rwanda, like Rwanda Bureau of Standard or Rwanda Regulatory Utilities responsible for the proper implementation of such kind of projects according to international quality assured

standards. So the proper antenna designing documents are required to be allowed to set up the antenna base station on Kalisimbi volcano.

4. THE BEST SYSTEM CONFIGURATION

The appropriate approach should be able to lead to a system of array of upgraded antennas capable of serving in the 5G technology, and provide strong signals without attenuation. The approach to the selection of the antenna types should also look to it that the selected antennas to be used in the array have the capabilities to serve in 5G technology. The 5G technology characteristics are already known so the setting up of this antenna base station should be in accordance to the technology capabilities.

5. GENERAL DESCRIPTION OF SYSTEM ARCHITECTURE

Below is the general block diagram of the system architecture, the system is made up of five multi-polarized antennas of microstrip type. These antennas are arranged in a way to transmit and receive strong non-attenuated signal of 5G technology. The arrangement includes position, direction and angles that these antennas are placed on.

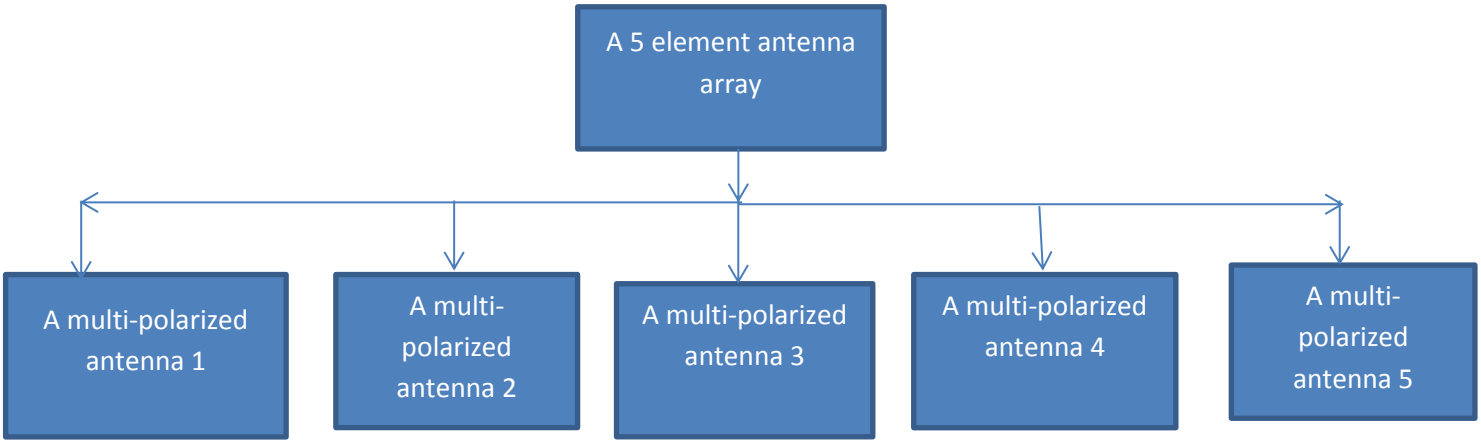


Fig 5. The block diagram of the general description of the system architecture.

5.1. Performance requirement validation for the proper implementation of this project.

The system must meet the following performance requirements:

Requirements	Measures
- Availability of electricity - 5G technology - Ratio - Quality of the antenna	- antenna downtilt and operation - 1GHz/s - 1 array of 5 element antennas - Multi-polarized antenna

5.2. Communication Using Base Stations that this project will use for implementation.

A base station communicates with mobile using control channels that carry control information and traffic channels that carry messages. Control channels are continuously used by the base station to transmit control information. When a mobile phone is switched on, it first scans the control channels and tunes to the one with the strongest signal. It then exchanges identification and authorization information with the base station and is ready to receive or send calls.

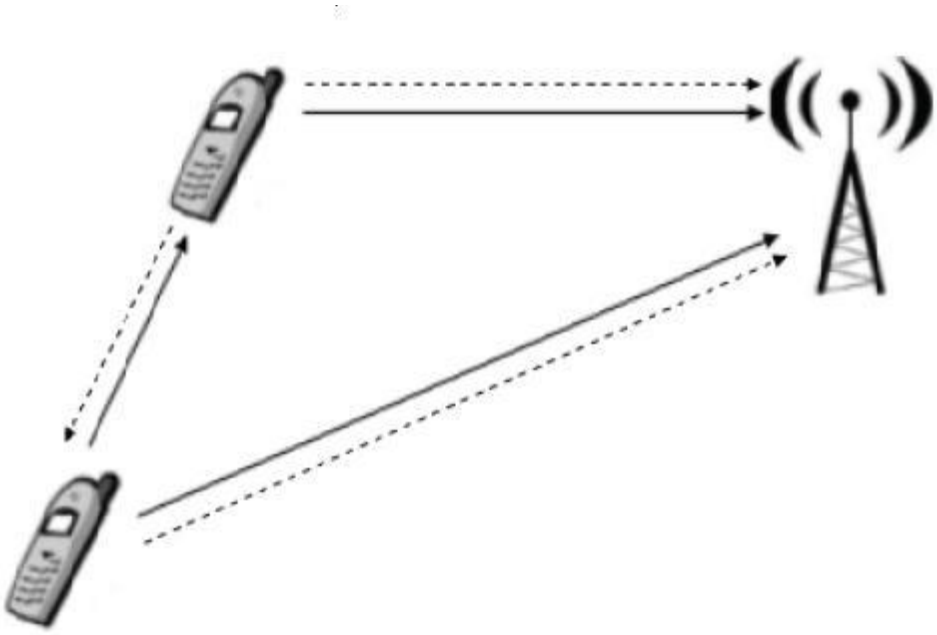


Fig. 5.2 Group Cooperative Communication

5.3. Cellular Fundamentals that this project will use to be implemented.

A cell is a term known as the area that is served by mobile phone system. Each cell contains one base station that is used to communicate with mobiles in that cell. It does so by transmitting and receiving signal on two radio links; one from base station to the mobile (down-link) and one from mobile to the base station (up-link). Each base station is connected to a mobile switching Centre (MSC) that connects calls to and from the base station to mobiles in other cells. The MSC is associated with a Public Switching Telephone Network (PSTN). The figure below depicts a typical setup using base station and switching centers.

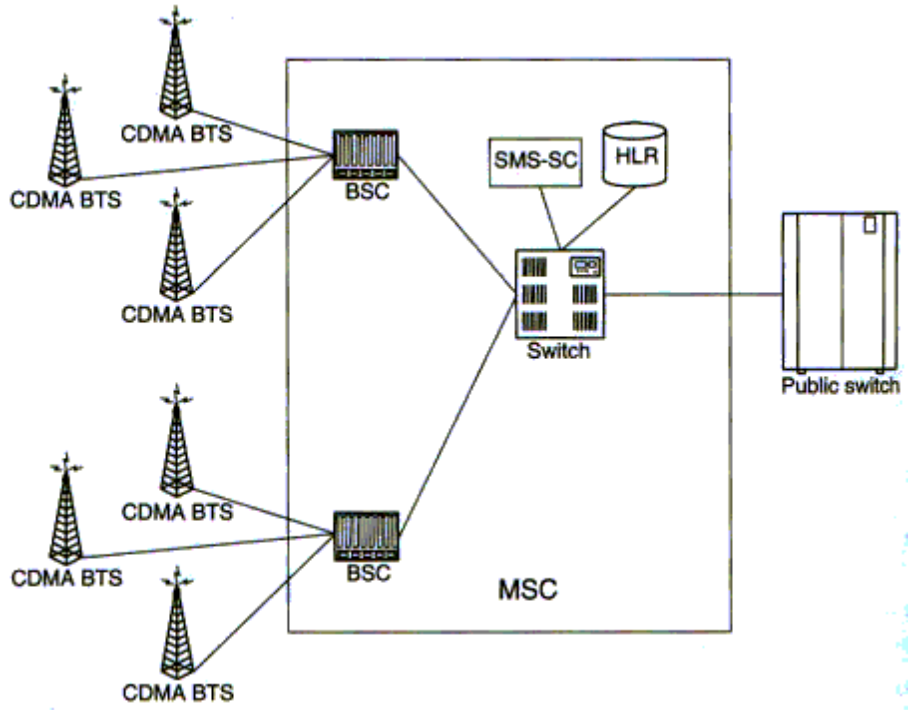


Figure 5.3. Typical cellular system setup

5.4. 5G Technology Features that this project has to work with.

The table below illustrates some of the 5G Technology features that this project will have to work with.

Technology Features	**5G**
Data bandwidth	1Gbps & Higher
standards	Single unified standard
Technology	Unified IP and seamless combination of broadband, LAN/WAN/PAN/WLAN and wwww
service	Dynamic information access, wear-able devices with AI capabilities
Multiple Access	CDMA(Code Division Multiple Access) & BDMA (**Beam Division Multiple Access)**

Core Network	INTERNET
Handoff	Horizontal & Vertical

5.5. Flat IP Network that this project will use for proper implementation.

Flat IP network is the key feature to make 5G acceptable for all kinds of technologies. In next generation of network, it is beneficial to transmit all voice, video and data using packet switching instead of circuit switching. Each mobile devises have to allocate IP based on connected network and its location. This technology reduces the number of component lower the operation cost and investment. Because of fewer central components to disrupt the system give low failure rate and lower latency.

5.6. Mobile Cloud Computing that this project has to provide.

Cloud computing is new and unique technique to access data like documents, application, video files, music file, etc. from any place without carrying any data-storage devices. By having all the information on cloud user can access all data from anywhere in the world any time. Best example of cloud computing is Gmail. In this service, all mails are stored on Gmail server, and also all processes are done on cloud. Users give the command then process occurs on Gmail's server, and result is displayed on a screen. It is the best for mobile applications where, the application runs on the specific device called cloud, and user can access the data and application. Requirement is user must have the internet not to have more computing capacity. It will also allow to feature mobile phone users having same data access like smart phone; difference is that feature phone data will not physically be stored on the phone.

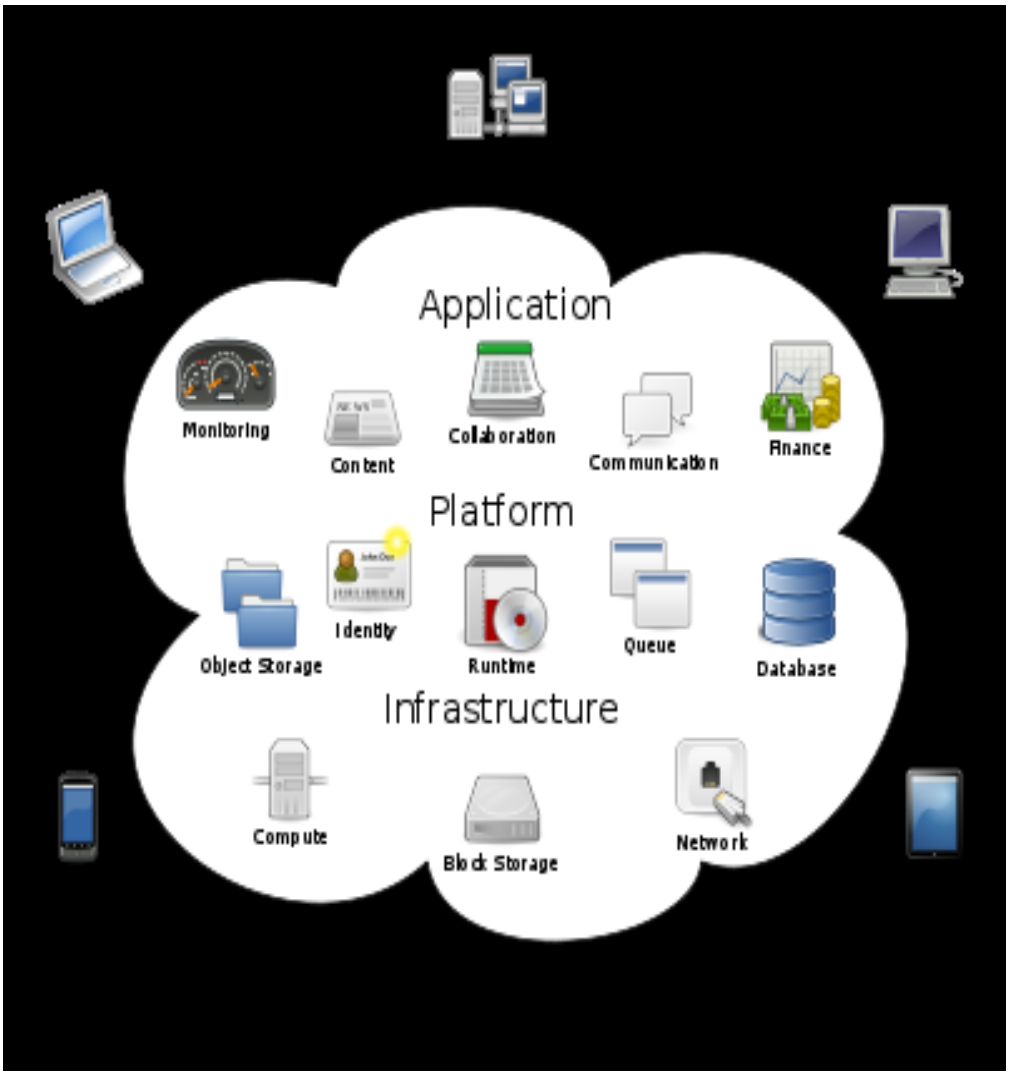


Fig.5.6. Cloud Computing

5.7. Power Control required for the project to be implemented.

Power control in cellular systems is very important process and allows that the mobile functions properly with received signal being large enough but not too high to cause any interference to other receivers. This is done by maintaining constant power level at the receiver by transmitter power control. The receiver tells the transmitter how much power is required, example. The base station would control the power level transmitted by the mobile phone and the mobile phone would control the received power by telling the transmitter the required level of power it needs to receive. This is done by mobile monitoring its received power and sending this information to the base station to control its power transmission. Power control minimizes the co-cell interference and reduces the near-far problem in CDMA systems.

5.8. Less Power Consumption by the new 5G base station, this is advantageous.

With increasing bit rates led to increased energy consumption in base satiations. Main challenge for 5G mobile networks is to reduce power consumption. In cellular networks base station consume more than 60% of the power so it is preferable to reduce power consumption in base station elements. Currently, networks are designed with the consideration of peak load not with medium and low load consideration. In real scenario if the load on a network increased, then coverage will decrease and load decrease, then coverage increase. To reduce the power consumption topology will design in such a way that as load on decrease base station starts to cover more regions, and we can shut down some of the base stations.

6. THE SYSTEM ENGINEERING PROCESS.

The Blanchard top-down approach is the best to be used to address the upgraded antenna array system in Rwanda on Kalisimbi volcano. This approach includes an initial definition of the problem (to be solved) and the identification of a consumer need, conductance of a feasibility analysis, development of system operational requirements and the maintenance and support concept, accomplishment of a functional analysis, allocation of requirements, and development of the top-level architecture for a given system, and so on. The process also continues with its last stages of construction and/or production, material and life-cycle support, and the system's retirement and disposal.

6.1. Definition of problem

Rwanda as a developing country has put much emphasis in the development of Information Communication Technologies, which is a strong engine for development. As Rwanda as well as in the whole world has seen the introduction of 5G technology, and this technology has no any antenna base station set up in the country yet, to allow Rwandans to exploit the good services of 5G technology. Hence, my project is 100% needed as a solution. Setting up one strong base station on Kalisimbi volcano, that will help Rwandans and other fellows in the region to enjoy the excellent services of 5G technology, is highly need solution to the problem.

6.2. System requirements.

The base station is required to be able to provide all the service capabilities of 5G technology. The base station is also required to provide a wide coverage covering the whole country. This requires the used antennas to be able to do that as well as the antenna array set up of the base station should be strong enough to provide that. The system should also be able to be 99% available, and have network coverage capable of serving the whole country of Rwanda. This concerns the availability of electrical power, antenna array arrangement; which means the direction, position and angles that the concerned antennas are placed on.

6.3. Feasibility Analysis

A feasibility analysis is accomplished with the objective of evaluating different technological approaches that may be considered in responding to the specified functional requirements. In considering different design approaches, alternative technology applications are investigated. In this project, after analysis of different antenna array types and antenna types, the only five microchip antennas will be used in a conformal array design, which will yield to the achievement of the system goals of serving in 5G technology in the whole country of Rwanda.

This project is feasible for implementation as there is only one 5G base station that will be in place, it is assured of market and high profits. The cost of the project is also feasible; In the first place, the upgrading of the antennas into multi-polarization character antennas will take an estimated cost of five millions US dollars and the designing of conformal arrays will take an estimated cost of fifteen millions US dollars. Hence a total of 20 million US dollars required for the whole project. And this cost is really feasible.

6.4. System Operational requirements

Current antennas used in Rwanda cannot be used in the 5G technology due to their low efficiency as the applications and services to be rendered in 5G technology require strong signals. Current antenna Arrays in Rwanda, also cannot work in 5G technology due to its higher bit rate of about more than 1GHz/s. Hence there is a strong need for a new designed antenna array with new upgraded antennas that are capable of working in Rwanda with 5G technology, given the following operational requirements;

The table below illustrates the **operational** requirements analysis in a detailed way.

Operational objectives	Operational requirement analysis
1. Using a new antenna that overcomes the deficiencies of most classical and less-than-optimum performing antennas that are widely produced today in Rwanda	Designing 5 multi-polarized antennas. With each one of them capable of producing a strong signal. This will be achieved by; Laboratory to design multi-polarization antennas Application of 5G technology Electrical power for antenna down tilt and base station antenna support

2. Designing a new antenna array that matches with the 5G technology in Rwanda, which has specialties contrast to current generations	Designing an antenna array on volcano Kalisimbi in Rwanda. Should be configured to form an array able to serve in 5G technology of high bit rate of more than 1GHz/s. Hence, this will be achieved by using; Five element antennas One cellular base station Application of 5G technology Laboratory to design an array for 5G cellular base station. Ensemble CAD Software High Frequency Structure Simulator (HFSS) Software Electrical power for antenna down tilt and base station antenna support

6.5. Maintenance and Support Concept

For a continued and sustained operating system, there is a strong need for all levels of maintenance that is; on organizational level, intermediate level and depot or supplier level. A sustained support is also needed. On the organizational level; there will be a need of an adequate electrical power availability check, for the base station to be up. Appropriate antenna positions, constant antenna software checks, constant antenna angle directions, and so on. On the intermediate level, there should be mobile and semi mobile maintenance activities which require skilled and semi-skilled laborers. The highest level of maintenance (depot or supplier) is required which requires highly skilled personnel to check the antenna programing technics, and propagation models for better antenna propagation. The automatic maintenance checking is highly recommended for the proper functioning of the base station.

6.6. Identification/prioritization of TPMs

The Technical performance requirements for this system, whose aim is to design upgraded antennas for 5g antenna array cellular base station on kalisimbi volcano in Rwanda has the following working targets of parameters of 5G Technology features, shown it the table below;

Parameters	5G
Frequency band	8-14GHz
Bandwidth	20-35MHz
Data rate	1Gbps and Higher
Multiple Access	Multi-carrier CDMA and BDMA
Mobile top speeds	More than 200Kmph

And the above specifications will enable the antenna array system to have the following performance working standards for as well as the antenna components of the system;

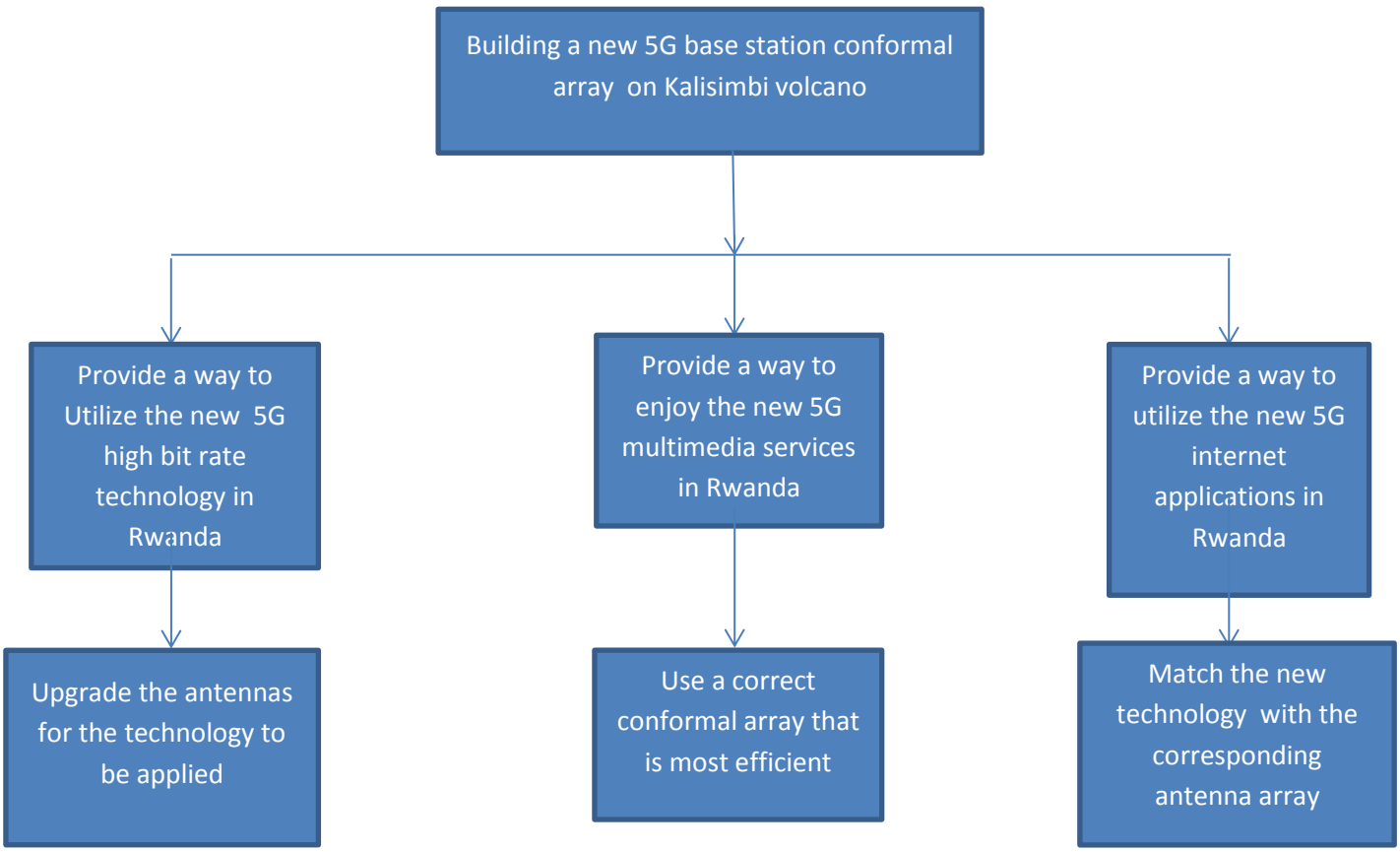
a) The system (antenna array) need to have the following standards of performance;

- It has to be system with best effective antenna types which are multi-polarized.
- A system that is capable of providing best strong signal without being attenuated.
- A system that is compatible to work with 5G technology able to work with more than 1GHz bit rates, and other 5G characteristics.
- A system that is well developed
- A system that is well assimilated
- A system with best results of service in 5G technology.
- Radiation efficiency

b) **The antennas** to be used need to have the following standards of performance;

- High antenna bandwidth
- High antenna gain
- Good antenna pattern
- Good Directivity
- Antenna multi polarization
- Power dissipation
- Main lobe
- Side lobe suppression
- Front-to-back ratio
- Input impedance
- Radiation efficiency
- Intermodulation suppression
- Construction
- Cost

The objective tree of TPMs



6.7. Functional Analysis

The functional analysis and formulation of this project is made up of;

- Five multi-polarized designed antennas
- The antennas are to be used to form an antenna array on Kalisimbi volcano in Rwanda.
- The array has to be designed to be able to serve or work in 5G technology
- The radii of curvatures of the antennas need to be designed well to provide the desired high performance.
- The antennas' spacing also need to be measured correctly to be able to work as desired with high performance.
- For the system to be able to function well; there has to a power supply for the base station support and antenna tilt
- The station also has to be managed by a network operation center which will be in Musanze district of Rwanda.

6.8. Requirements allocation

For the system to be well managed and function effectively; it will be split up into components. The base station antenna array has five antennas components; which are further divided into smaller components like antenna extension cables, surge suppressors mount, and so on. All these parts need to be properly allocated in their respective positions and functions and properly integrated, for proper functioning of the base station.

6.9. Synthesis, Analysis, Design Optimization

According to system performance measures, all the system components before being used to synthesize a system, they are analyzed to ensure the proper evaluation of what is required of the system, and finally optimized to select the best method to design the system. This step is done to ensure, the correct approach to the system synthesis, which is according to the system requirements.

6.10. Design integration

The best approach that is selected using design optimization is the one used in design integration. This approach has to be the best to make the system feasible, functional, environmental friendly, easily maintained and so on. This integration has also to be according to system requirements. The antennas have to be properly integrated to form a full array.

6.11. System Test and Evaluation

With the help of the four testing types; type 1, type 2, type 3 and type 4; there has to be an extensive test and evaluation period to ensure that the system set up of the antennas is according to the requirements. And this action has to be done on every level of the system process progress, so that in case of any incompatibilities, they can be fixed earlier in the process.

6.12. Construction and/or Production

After the all the checking through the previous processes, then the next step is construction and/or production of the system in the estimated required enough units. This has to be according to the system requirements previously set. According to our system, there will be a complete construction of one antenna array set up on Kalisimbi volcano which will form a strong base station to serve in the whole country of Rwanda.

6.13. Operational use and Life-cycle Support

After the system is constructed according to the optimized approach and in line with the system requirements, it is now ready to be deployed and operated or used the intended job or need. In this regard, the system requires the sustaining life-cycle support maintenance for the continued operation of the system and necessary upgrades and modifications according to the technology evolutions or development.

6.14. Retirement and Material Disposal

The system's retirement has also to be put into considerations. This concerns how the system is disposed after it retires which has to be properly done and does not have to cause any negative effects on either the environment or people. This also concerns if the system is recycled. In case of our system, after the system retires, it has to be properly disposed in a way that does not affect people and the environment.

7. THE 5G ANTENNA ARRAY BASE STATION TECHNICAL PROGRAM PLANNING, IMPLEMENTATION, AND CONTROL.

The 5G antenna array is very wide project that needs a high standardized technical program planning, implementation and control. The activities involved in this project range from those that require skilled laborers and non-skilled laborers.

7.1. PROGRAM REQUIREMENTS/STATEMENT OF WORK (SOW)

For the proper implementation of this project, there has to be documents explaining how the project is to be accomplished always, for all the concerned members of the project to refer to, in order to remain on the track of the system requirements.
Among the necessary requirements we have;

1. **The name of the project:** This project needs to have a unique name, in order to be identified and recognized. In this, regard, this project will be called ''5G KALISIMBI BASE STATION. This will allow easy follow-up and control of the project without confusing it with other projects. It will also make the project accountability easy.

2. **Project main objectives:** Without clear guidelines and documented objectives, it can be difficult to achieve the goals of the project. The main objectives of the 5G Kalisimbi base station are;
    - Designing a proposed new array of antennas that will provide a stronger signal for the intended 5G applications to be applied in Rwanda.
    - Using a new antenna that overcomes the deficiencies of most classical and less-than-optimum performing antennas that are widely produced today in Rwanda.
    - Designing the antenna that matches with the 5G technology in Rwanda, which has the following specialties contrast to current generations.

3. **Suppliers:** This project will have a variety of suppliers due to the concerned different activities involved. Most of the suppliers will be within the country, and a few from outside the country depending on the materials supplied.

A) Suppliers from within the country.

Among the suppliers to this project in Rwanda we have;

a) **Infrastructure material supplier**: The base station will need the construction of the needed infrastructures to help the proper operation of the base station; hence these materials will be supplied by a supplier as a result of tender boards or other selection methods.

b) **Electrical power supplier**: As this project will require electrical power on a full time basis, there will be an electrical power supplier which may be Energy Water and Sanitation (EWSA) Company that is currently the only electrical power supplier in Rwanda.

c) **Network Operation center (NOC) equipment's suppliers**: There will be a need for supplying office equipment for offices and hence that supplier need. **Skilled labor supplier**: This includes Engineers, software programmers and technicians to work on the base station. These will be supplied by integrated polytechnic colleges in Rwanda as well as Colleges of Science and technology in Rwanda. Some experts

d) **Non-skilled and Semi-labor suppliers:** These will come from different companies or associations of laborers from within the area. Among these we have security guards from security companies.

e) **Drinks and food suppliers:** All the personnel working on the base station will need food and drinks, hence, there will be a need for a restaurant or any other food and drink supplying organ.

A) Suppliers from either inside or outside the country.

a) Antennas and other telecommunication equipment: Among others we have dishes, antenna cables, routers and other components. All these can be from either supplier within the country or outside Rwanda.

b) Security equipment: The equipment either for the security of people or system, can be supplied from within the country or from outside the country**.**

c) **Repair parts or Spare parts suppliers:** These equipments can also be from suppliers outside of inside the country.

4. Engineering disciplines

The 5G Kalisimbi base station will require a blend of nearly all engineering disciplines, in order to operate properly. Among others we have, Telecommunications Engineering, Electronics Engineering, Electrical Engineering, software engineering, Reliability Engineering, Maintainability Engineering, Environmental engineering, Security Engineering, Safety Engineering, Human factors Engineering, Logistics and Support Engineering, Disposability Engineering, to mention but a few.

5. Administration

There will be a need for bureaucracy officials for better accountability and project representation either to the Government of Rwanda or internationally. These officials have to ensure the systematic implementation of the project.

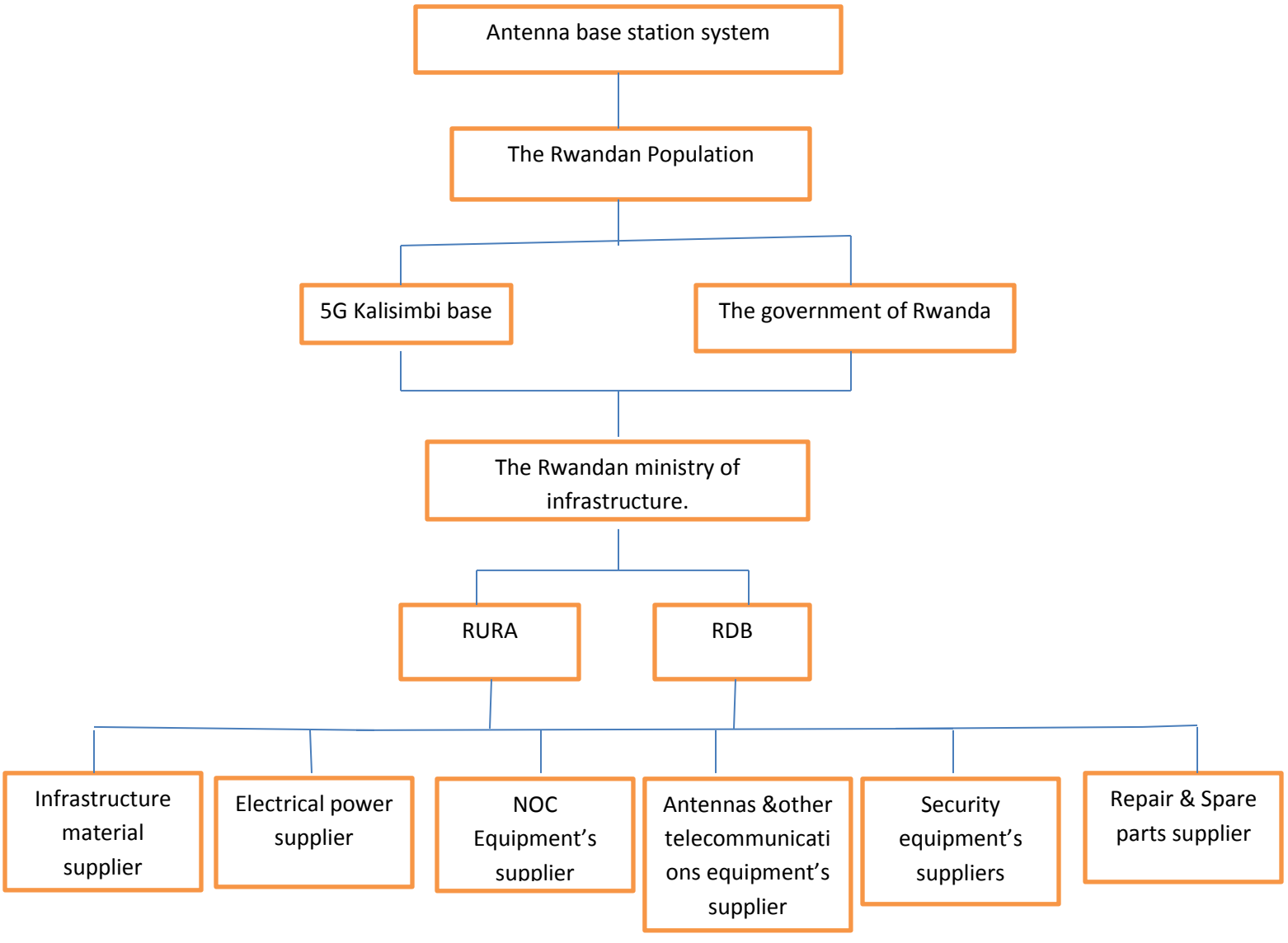
6. System management

The system management is a vital part in the project implementation as it plays a role of coordination among all the activities taking place in the project, be technical activities, management activities and hence creates a good team work for the smooth implementation of the project.

Consumer, producer, and supplier interfaces.

In 5G Kalisimbi base station project, the consumers are the population of Rwanda living in the country, starting from Musanze district where the base station will be constructed. Among the producers we have the government of Rwanda which will be needed to provide a big percentage of the support. This can be done through government agencies like Rwanda Regulatory Utilities (RURA) or Rwanda Development Board (RDB). Other, partners also may be part of the project producers. A variety of suppliers as described previously will play a big role in the project implementation.

The illustration in a block diagram



7.2. ORGANIZATION IN 5G KALISIMBI BASE STATION

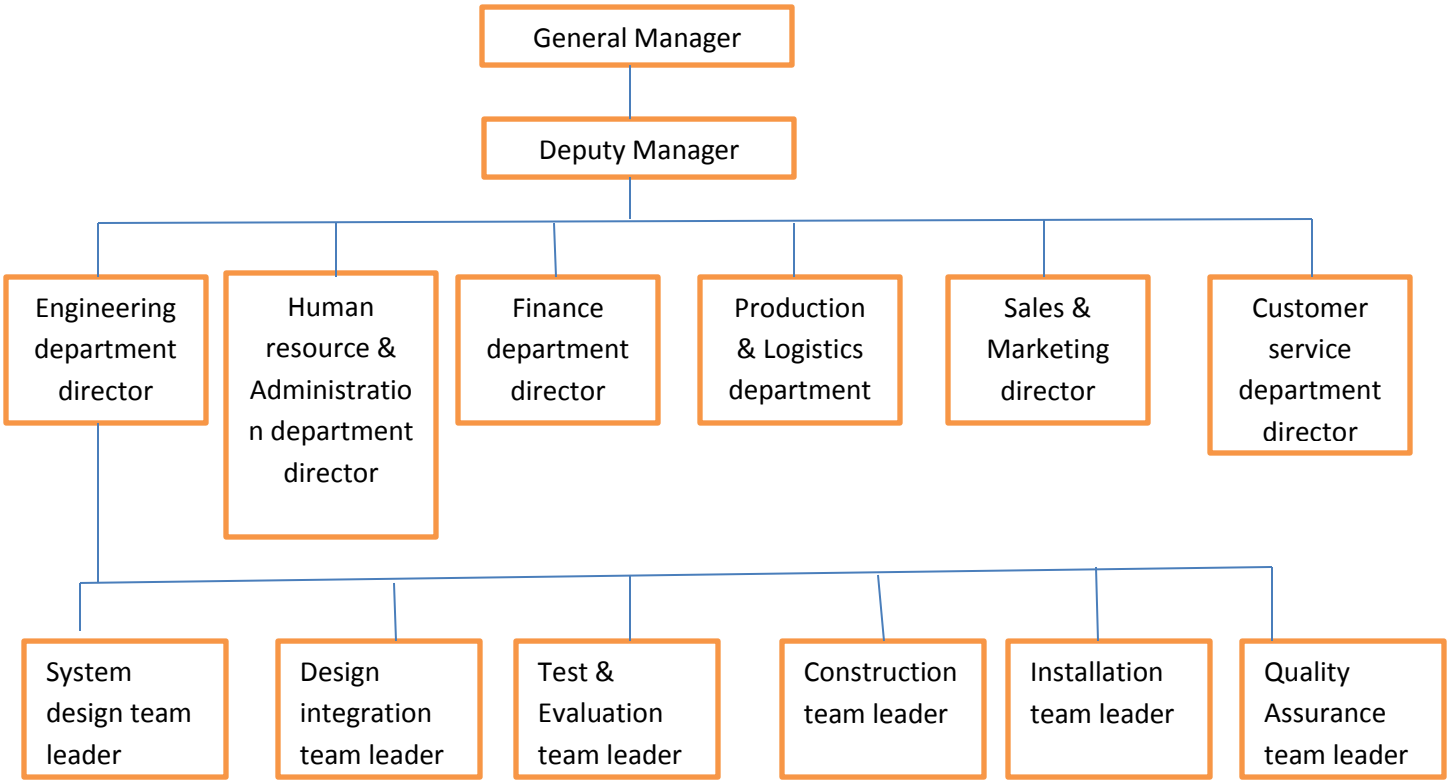
In order for the project to achieve all the requirements and doesn't lose track, there has to be appropriate organization of all the concerned activities, and responsible personnel. This creation of responsibility leads to better accountability. Organization also eases team work where there is always availability of support from one department to the other, for the smooth progress of the project implementation. The organizations of trainings also are put into considerations.

7.2.1. PRODUCER/CONTRACTOR ORGANIZATION/5G KALISIMBI BASE STATION BUREACRACY ORGANIZATION.

For this project's organization we will have the following levels;

- **Manager:** The manager is the very top official who has to be aware of every activity from every corner, taking place in the project. He/she has to be informed by his/her deputy manager (level directly below him/her).He/she has to be highly experienced and has a PhD or master's degree in management courses.
- **Deputy Manager:** This is the second to the manager. It is also a top level position; he/she coordinates all the work activities, on the field and in the offices. He/she reports directly to the manager. He/she has to be highly experienced and hold a PHD or master's degree in management courses.
- **Directors:** The project will have different departments like, finance department, System engineering, human resource, Logistics and so on. All these departments have will have their representatives/directors where each director will be in charge of all the activities taking place in his/her department and give a report on a weekly basis, or monthly basis. These also need to be experienced in their respective fields of departments and have at least a master's degree.
- **Chief technicians:** Due to a variety of technical activities**,** each section can be given a chief technician to manage its activities on a section level and give a report to the concerned director. He/she needs to be experienced in his/her work and have at least a High level diploma.
- **Team leaders:** For proper working order, there have to be team leaders to lead on site on everyday basis**.** These results into high work progress and manpower utilized fully to yield the project implementation. Team leaders also need to be experienced in their work and skilled in what they do and lead others to do.

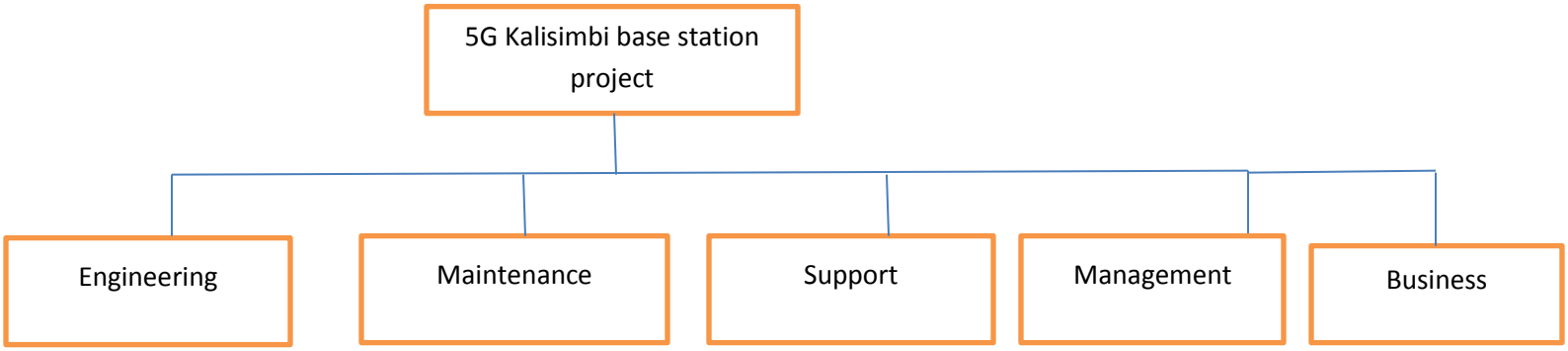
5G Kalisimbi Base station Product organization structure



7.2.2. SYSTEM ENGINEERING ORGANIZATION WITH OTHER PROJECT PARTS

Although this is a 90% engineering activity, but this project requires working well with other parts of the project for proper implementation on time. There has to be an organized way of how engineering work is coordinated with business and management activities.

5G Kalisimbi Base station System engineering organization blocks diagram



7.2.3. SUPPLIER REQUIREMENTS

As seen previously, this project will need a bunch of different suppliers with different items or products to offer to the project for proper implementation. There has to rules and regulations for these suppliers for smooth progress of the project implementation. Among others, these suppliers are required of the following;

- To deliver items of high quality standard approved internationally.
- To deliver all the sums of products or items as required by the project
- To deliver the products or items on time.
- To deliver only the items with the agreed characteristics; for example, dimensions, weight, date of manufacture and expiry.
- They have to exercise professional conducts and ethics.

Generally, these suppliers have to abide by all the conditions in the contracts and where necessary apply professional conducts in judgments.

7.2.4. HUMAN RESOURCE REQUIREMENTS

The human resource level is concerned with the following;

- Recruiting and well-being of all the employees or members of the project.
- It is required to recruit competent members to work on the project,
- Arrange and provide trainings where it is required,
- See to it that all the rights of the each member are considered,
- Encourage professional conducts and ethics, self-respect and respecting others (co-workers).
- Arrange how members are cared for, like getting insured, salaries, loans, contracts or any other necessary certificates.

The leaders have to be role models to the ones they lead, though it is one's duty to do his/her responsibilities well and be accountable. The human resource management is a coordinating level in the company or project like this that is concerned with creating a good working environment for every member to enjoy.

7.3. KEY ORGANIZATIONAL INTERFACES IN 5G KALISIMBI BASE STATION SYSTEM.

5G Kalisimbi base station will be in operation on a full time basis. This means that, the system will have to be up or in operation twenty four hours a day, seven days a week. Hence, it will better to work in shifts for better service to be rendered as it will require full concentration on screens regulating the base station to keep operation.

All the mentioned activities will be carried out in a Network Operation Center (NOC), which will also be established in Musanze town. There will be a need for brief daily meetings, for all the employees to be on the same pace, introducing new upgrades or announcing challenges and failures.

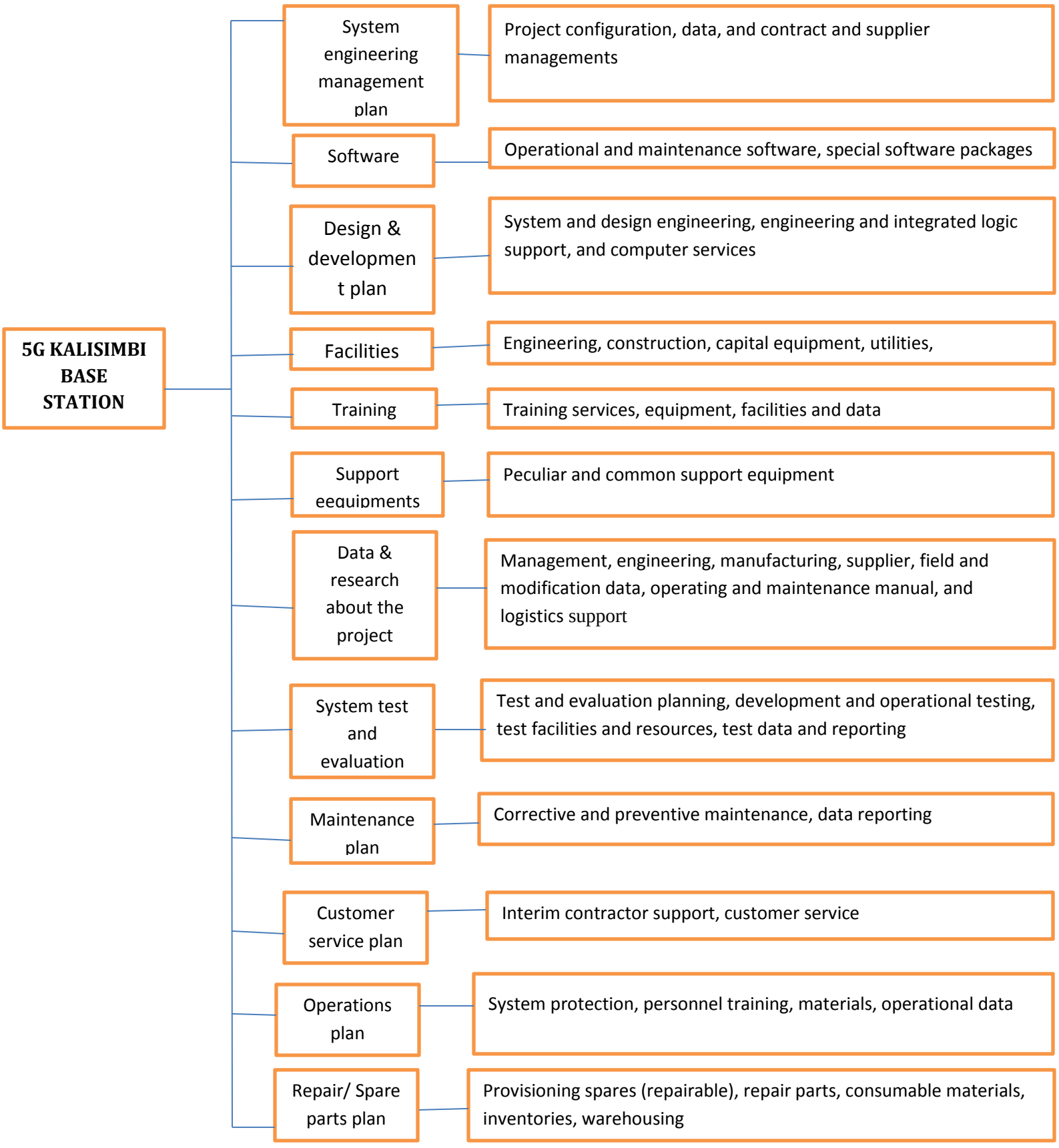
Weekly or monthly meetings are also need for extensive evaluation. Evaluations can also be from getting feedback from the population around. Scheduled trainings are also needed for proper modifications and upgrades, to keep current in the field.

7.4. 5G KALISIMBI BASE STATION SYSTEM WORK BREAKDOWN STRUCTURE (WBS)

Three levels will be used to describe the work breakdown structure of 5G Kalisimbi base station system. This level is very crucial in the system development as it sets clearly a plan of how activities will be done.

The first level: This is the picture that one will directly have in mind if he/she hears of 5G Kalisimbi base station, and this will be a base station that will provide clear, strong signals, with super 5G services.
The second level: This relates to the needed or required activity components or constituents that will be needed for 5G Kalisimbi base station project to be implemented.
The third level: This level is concerned with the detailed plan of activities that need to be performed, how they are linked together and how they should be performed.

The block diagram below shows a detailed WBS for the 5G Kalisimbi base station system



7.5 PROJECT SCHEDULE

A maximum of Fifteen months is the time required for this system to be in operation. Firstly all the surveys on the site are done, the nature of the geographical location, availability of all the requirements. Later, there comes construction and development, and lastly operation and maintenance of the project. Briefly this time is spent doing the following;

1. **5G Kalisimbi Target missions:** Achieving the project's missions and objectives is the priority to be considered as an engine for the project implementation. Every activity performed should be referring to achieving the mission of the project. Hence, to clarify this, a group of experts from the project members gather and compile the project missions/objectives in a document as a reference for everybody. One month is enough for this activity to be completed.

2. **Rwandan population's need /requirements:** This project is to allow Rwandans to be able to enjoy 5G technology services; hence, this base station should be able to provide 5G technology services to Rwandans in the country. The mentioned group of experts also identifies all the customer requirements and ways of how these requirements can be achieve. One month period is enough for this.

3. **Both internal and External Competitive analysis/Market:** Currently, there is no any other company that has set any 5G base station in Rwanda. This does not leave behind this stage of competitive analysis of any competitors who would come up in the future to compete with the services rendered by our system. A team of experts needs to identify all competing factors that any advisory can come up with to make our system lose. And all those factors need to be addressed as early as possible. Three weeks are assigned for this.

4. **5G Kalisimbi System specification:** This stage needs a team of system engineers, designers and technical experts to gather and identify all technical specifications of our system. This may range from looking at the base station as a whole, antenna array propagation, or antenna type specifications that our system will use. Five weeks are enough for this.

5. **5G Kalisimbi Project planning/WBS:** For the successful implementation of our project ,a team with expertise in management and planning will need to gather and come up with a clear plan of how all the project activities will be carried out. This includes, schedules, different activities that will be carried out and the times these activities will be carried out, responsible personnel, equipment that will be used, how these equipment will be kept, cost, work breakdown structure and so on. Two weeks are enough.

6. **5G Kalisimbi Concept development:** This stage will require a team of technical experts led by a system engineer to identify all the steps and activities required for our system's concept development. This includes matching the customer requirements with the system specifications to achieve those requirements. One month is assigned for this.

7. **Project plan:** This project plan will link the plan/WBS previously mentioned and incorporate the concept development planning. This plan has to clarify how and when needs analysis, concept exploration and concept selection stages for our system are going to be carried out. Two weeks are assigned for this.

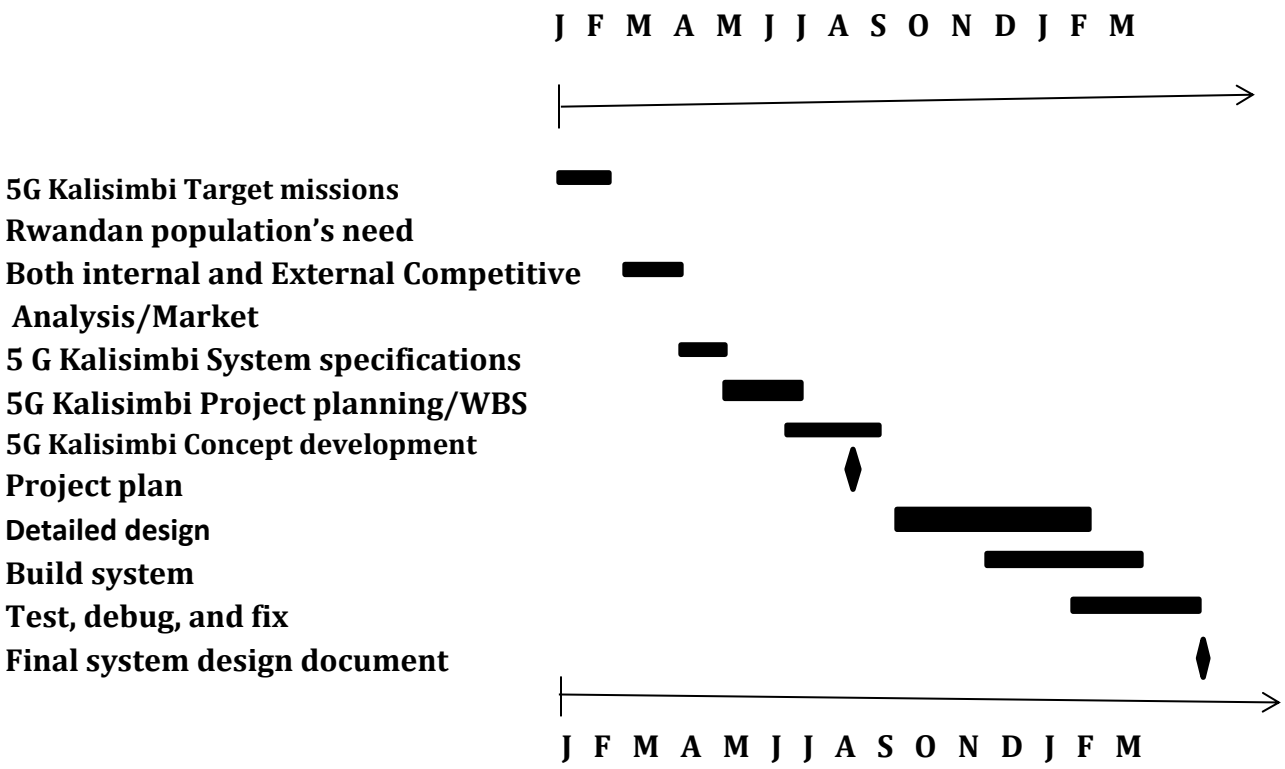
8. **Detailed design:** A team of designers will also gather to design our system in a detailed way. This will identify how the base station will be set up, antenna array arrangement, antenna directions and angles, positions and so on. This design has to be in line with the system requirements and objectives to be accomplished. Five months are assigned for this.

9. **Build system**: After the design is completed, the following stage will be to construct of to build up the system, according to the detailed design, this stage is very critical and it requires a strong team of experts from all the concerned fields and engineering disciplines, management members and others to get involved and ensure the proper implementation of the project, that is to say the correct setting up or construction of the system. Four months are assigned for this.

10. **Test, debug, and fix:** As the system will be in the construction process, it will have to be tested on a frequent basis and find if it is operating as required on every level of development, and in case of any failures, they will have to be addressed as early as possible. Testing is a continuous process, on every step of system progress there have to be testing, you don't wait until a system is completely built and then test, you test as you build it. Three months is assigned for this activity.

11. **Final system design document:** After everything is working well, a system ready to be operated, there will have to be a document of every activity performed on the project, how it was built, materials used, conformance to drawings and material requirements, all the changes made, all the steps made and so on. This document is very important in case of system failure, or for further similar system developments or our system upgrades. Two weeks are allocated for this stage.

Gantt chart


J F M A M J J A S O N D J F M
5G Kalisimbi Target missions
Rwandan population's need
Both internal and External Competitive
Analysis/Market
5 G Kalisimbi System specifications
5G Kalisimbi Project planning/WBS
5G Kalisimbi Concept development
Project plan
Detailed design
Build system
Test, debug, and fix
Final system design document
J F M A M J J A S O N D J F M

7.6. TECHNICAL PERFORMANCE MEASURES (TPM's) TRACKING

For proper implementation of the 5G kalisimbi base station project, there will be a number of tracking Technical performance measures; among others we have the following;

1. **Availability:** In the first place, the system will have to be 99% available, in this regard; the system will have to be always up and in proper operation. In case of any maintenance activities, the late nights will be a good time for such. As most people are asleep during the nights and hence don't need use the base station at nights.

2. **Reliability:** Under specified operating system requirements, the system has to have a high probability of proper operation till its end of life. This period of operational time has to be clearly determined. The system will have to be capable of operation in a satisfactory manner till its end of life.

3. **Capacity/weight:** The 5G Kalisimbi base station will have the capacity to serve all the Rwandan population which is approximately Twelve Millions. The will have to be designed strong enough to serve properly that number of people without failure. The coverage and strong un attenuated signal will be needed to be provided by the system.

4. **Maintainability:** 5G Kalisimbi base station will have to be maintainable on a manageable level. Here I mean, there will be no difficulty in finding spare parts when necessary, manpower to work on the system and so on.

5. **Parameters**: The system will have to provide 5G technology services, either in voice, data services, videos and other applications.

6. **Frequency band:** This system is required to provide signals with at least 8-14GHz frequency band. Below this range, the system will be out of measure.

7. **Bandwidth:** This system is required to provide signals within 20-35MHz bandwidth. Out of this range, the system will be out of measure.

8. **Data rate:** This system is required to provide signals with 1Gbps and higher bit rate. Below this rate, the system will be out of measure.

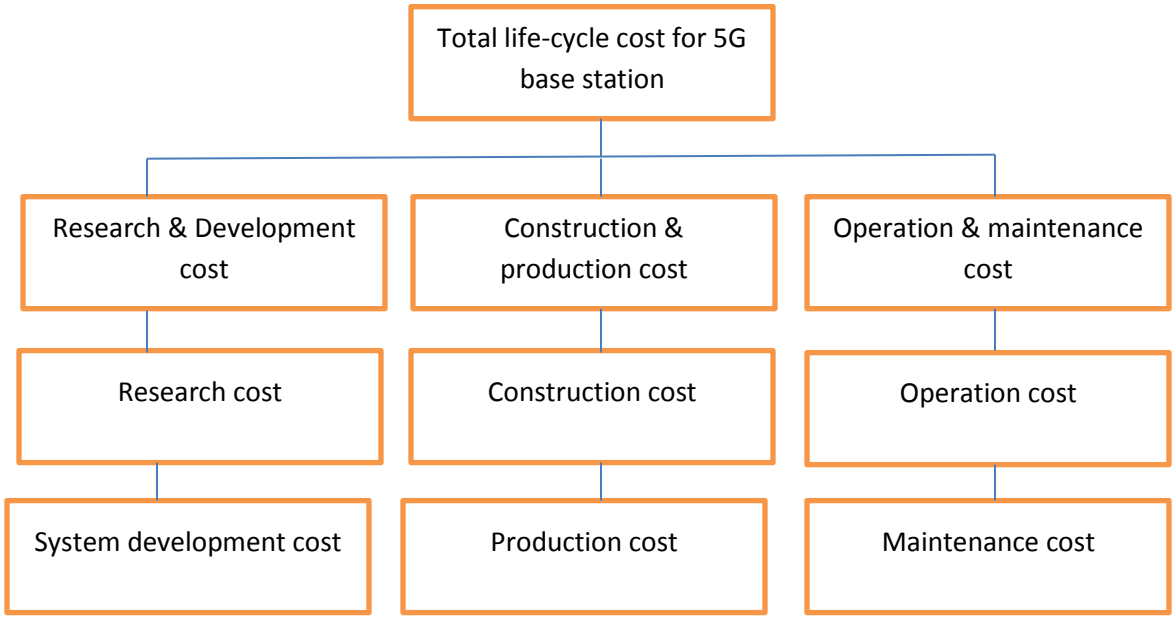
9. **Multiple Accesses:** This system is required to provide Multi-carrier CDMA and BDMA accesses.

10. **Mobile top speeds:** This system is required to provide signals with more than 200Kmph.Below this speed; the system will be out of measure.

7.7. PROGRAM COST FOR IN 5G KALISIMBI BASE STATION SYSTEM.

Every stage in the system development process is costly, that's why budgeting for the total cost of the system is a vital part of the system development. Actually if the project is not feasible in terms of cost, the project cannot be implemented as every activity is costly. Generally, there will be research and development cost, construction cost, operation and maintenance cost. Currently, we will not include material disposal and phase-out cost for our system.

Cost Breakdown Structure (CBS) for 5G Kalisimbi base station.



General estimated Life-cycle cost table for 5G Kalisimbi base station.

Project Budget ($)		
Research & development cost	Management Plan cost	10,000
	Advanced development	15,000
	Design Cost	17,000
	Design support cost	10,000
	Prototype cost	12,000
	Test & Evaluation cost	19,000
	Material cost	18,000
Construction cost and production cost	Construction cost	60,000
	Test and Evaluation cost.	19,000
	Quality cost	5,000
Operation & Maintenance cost	System operation cost	95,000
	Maintenance support cost	55,000
AOB		29,000
System retirement		25,000
Taxes		10,000
Total		**399,000**

7.8 TECHNICAL COMMUNICATIONS

For a successful system development, communication among all the members working on the system is essential. This allows smooth progress of the process, and allows everyone to remain updated on every progress on the system, allows notifications among the members on avoiding repeating any mistake encountered before, notification of any necessary changes made by any member, and so on. The following are tools that will be used for communication in our project implementation;

1. **Short/brief meetings:** Daily meetings normally at beginning of any shift or activity allow some important and urgent announcements, or quick notifications.
2. **Telephones:** Cellphones or fixed/land line phones are common and quick means of communication that will be used in this system development.
3. **Telefax:** This is also helpful in communication; it will also be used where necessary.
4. **Notice Boards:** Are also quick ways of notification that will be used by the employees on site for communication.
5. **Internet:** This is also a common way of communication that will be used in our project implementation. All kinds of communications using internet like e-mail or any social media communication. This can be on a computer or any electronic devices, like phones, tablets or any other.
6. **Reports:** These are documents that include all the information about system development. These may be handovers, daily, weekly, monthly, annual reports and includes all the activities carried out in the system development.
7. **Mail boxes:** This type of communication will also be used whenever it will be necessary.

7.9. PROGRAM MONITORING AND CONTROL.

There is a strong need for program monitoring and control for the proper project implementation and according to the planned schedule. The best tool that will be used for better control and monitoring, is appointing team leaders on the lowest level of manpower, to supervise every activity and give report to the high ranking official through level by level. Rules and regulations regarding the system requirements also have to be available for every member to have access to and act referring to the system requirements. Evaluations and reviews also will have to be done on a regular basis either in meetings or personal to personal interviews, to keep everything on track. This can also be done through seeking feedback from the beneficiaries that is; Rwandan population in the country.

8. ENGINEERING SPECIALTY INTEGRATION

5G Kalisimbi base station is a system that will use a variety of engineering disciplines; among others, we have Software engineering, Telecommunications engineering, Electronics engineering, Electrical Engineering and so on. These Engineering disciplines need to be properly integrated and work together, each discipline fulfilling its role in the system development for the successful project implementation. There should be a smooth communication and understanding between the leaders of these disciplines working on this system.

8.1. FUNCTIONAL ENGINEERING

In order for all the Engineering disciplines that will be involved in the 5G base station system development to work together, there will be a need of Functional Engineering. This form of Engineering will ensure coordination and working together of all the Concerned Engineering disciplines. This level of management will have a senior manager and his staff working hand in hand with the leaders of all the engineering disciplines involved in the system development.

8.2. SOFTWARE ENGINEERING

5G base station system will need software programs to be able to operate properly. Software Engineering is very crucial in the antenna propagation and hence, in signal transmissions and receptions. The Network Operation Center also uses software programs for controlling the base station operations, and identifying failures.

The Technology used in designing 5G Kalisimbi base station system also uses Software programs in to accomplish designing activity. This is used in determining antenna angle positions/directions.

8.2.2. Technology Assessment used in determining Antenna positions uses Software programs.

- Ensemble CAD Software; It is used to model elements and small arrays with a high degree of accuracy and has the ability to determine all the relevant electrical parameters for various antenna shapes, layers and array feed networks.
- High Frequency Structure Simulator (HFSS) Software; HFSS is a 3D EM simulation software for RF & wireless design which is produced by Agilent Technologies.
- Multi-polarization
- Electrical power for antenna down tilt and base station antenna support

PC Hardware Requirements for HFSS Simulations

Due to the very complex nature in which HFSS performs its simulations and calculations the software requires following hardware requirements:

•RAM of 4GB
• 16 hours for each simulation on a computer using Pentium III 500 MHz or faster

Due to these hardware requirements the final system can only be limited to a single five-element array instead of the fully cylindrical array with rows and columns of antenna elements.

All the above design activities use software programs.

8.3. RELIABILITY ENGINEERING

Reliability engineering is very necessary this system development as the reliability engineers will ensure that the system performance will be according to the system performance requirements, in the given time of operation. In case of any failures of the system, reliability engineers will notify that and be addressed. In order for Reliability engineers to accomplish their system operation missions, they will have to work hand in hand with other engineering disciplines and ensure their proper functioning.

8.4. MAINTAINABILITY ENGINEERING

All kinds of maintenance will be needed to keep the system in operation. Scheduled preventive maintenance activities, to check if everything is ok in all parts of the system. Unscheduled corrective maintenance activities will also be done in case of any emergency failure identified.

8.5. HUMAN-FACTORS ENGINEERING

Ninety nine percent of this system will need human interactions in its operation. Human-factors engineering therefore is strongly needed in this process in order to deal with proper humans-interactions with the system operations, putting into considerations human capabilities and limitations. Physiological and Psychological human factors and so on.

8.6. SUPPORTABILITY ENGINEERING

The system will also need a long-term sustainable maintenance support. For proper continuous operation of the system, Support engineering discipline is very important in the life-cycle of the system.

8.7. QUALITY ENGINEERING

Quality services are a big priority in 5G Kalisimbi base station system development. The role of this discipline is to ensure that Rwandan people's needs or requirements of using and enjoying 5G technology services are met or even exceedingly met. This level of control ensures that all equipment used, materials used, methods used, and so on are all of quality standards. It uses some tools like Quality deployment function, to help accomplish these tasks.

8.8. ENVIRONMENTAL ENGINEERING

Environment Engineering is an Engineering discipline that is concerned with environmental conservation. Setting up a base station on a volcano has to deal with any negative system impacts on either the surrounding people, that Musanze district residents or even the environment around, like rivers, lakes, forests and so on. The system negative impacts may be deforestation, soil degradation, displacing people's homes due to base station construction, the base station noise, and so on.

8.9. DISPOSABILITY ENGINEERING

This engineering discipline will play a vital role of 5G Kalisimbi base station system material disposal. After the system will be retired, the system component materials will be required to be properly disposed or recycled if possible. If these materials are not properly disposed, they can damage either the environment or be poisonous or dangerous to people. All these duties are for Disposability engineers who are experts in addressing and handling such cases.

8.10. VALUE/COST ENGINEERING

This Engineering discipline will be concern with the system total life-cycle cost. This is also important in system development as every part of system development is costly. And if the costs are not managed well, this can be a barrier to the system development. These particular engineers evaluate the system total cost, starting with Research and development costs, construction and production costs, operation and maintenance costs, Retirement and material disposal phase-out costs.

9. CONFIGURATION MANAGEMENT (CM)

The functional and physical characteristics of the 5G kalisimbi base station will need to be identified, documented and audited. This task is accomplished by the configuration management approach. This goes hand in hand with recording system configuration and controlling the changes made to the system during system development process. Configuration management helps to provide a complete audit trail of design decisions and system modifications. It is a concept of baseline management which includes the definition of the functional, allocated and product baselines of the system.

10. DATA MANAGEMENT (DM)

All data from system development process and system operation has to be kept appropriately. There will be hard copies filed in files and kept properly. There will also be databases and computers to save the project private information. This will require security credentials to access any data.

10.1. DESIGN DATA

For proper identification of data, data will be kept differently to avoid confusion. There will be design documents with all design data only. In case design data is needed either for making some changes or modifications by any authorized personnel, design data will be readily available.

10.2. TEST DATA

Test data will also be documented properly and separately. This will enable any authorized personnel to use test data whenever required. This will also require credentials like username and password for security purposes.

10.3. REQUIREMENTS DATA

Requirements data will be the reference for the 5G Kalisimbi base station, this data will also be kept or documented properly and separately for easy access ability of any concerned personnel in need. This data will always be needed during system development for system requirements evaluation with respect to the system development progress. This will enable the team working on the system to remain on track and keep working within the system requirements boundaries.

11. RISK MANAGEMENT PLAN

In the development of a system like 5G Kalisimbi base station, there has to be a very well prepared Risk management plan in order to avoid risks and enable the successful system operation. In this project, Risk management plan is essential to identify all the risks that can be encountered in system development either on the system or surrounding environment, humans inclusive. After identifying those risks and their causes, the plan goes on to deal with these risks, how they can be avoided, controlled, or eliminated, for better implementation of the project. Risk management plan includes the following;

11.1. RISK ASSESSMENT

This is the part of Risk management plan identifies potential areas of risks by showing the likelihood of failure and evaluates the impact of that failure. This enables the concerned team to know what is required to deal with a particular risk and how serious it is. This is a duty of every employee to control every part of the system, mostly technical chambers, though risks can also be in non-technical chambers but mostly of less impact. In case there any risk identified it has to be addressed immediately.

11.2. RISK ANALYSIS

This part of Risk management plan deals with analysis of risks, their causes, and their impacts using different Risk analysis tools like hazard analysis and trade-off analysis. This part requires personnel with Risk analysis skills, well trained and capable of using Risk analysis tools. This part will help identify different kinds of risks and their levels of impact, and hence deal with them accordingly. Identifying the cause(s), the effects, and the magnitude of the risk perceived, will help identifying alternative approaches for risk avoidance.

11.3. RISK ABATEMENT

Risk abatement or risk mitigation is a part of Risk management plan concerned with the all the methods that can be applied to reduce (or eliminate) or control the risk. Among others, in 5G Kalisimbi base station, 5S (Orange excellence regulations), technique or method will be commonly used on a daily basis, in the mornings or evenings, at the beginning of every activity. This will be applied in both technical areas and non-technical areas. This method in addition to other methods will help mitigate risks in the 5G Kalisimbi base station. 5S method includes the following;

Sort: This refers to proper arrangement of things and activities in order. This avoids vacant spaces and idle periods in the system development process. Sorting also helps locate items and identify those with failure easily. It helps also maximize labor hours with a good harvest with no time wasted.

Straighten: This also refers to putting things in the proper order and clarify everything that is not clear.

Shine: This is related to make everything to the best. Make something to shine refers to make it look best, with high level of cleanliness.

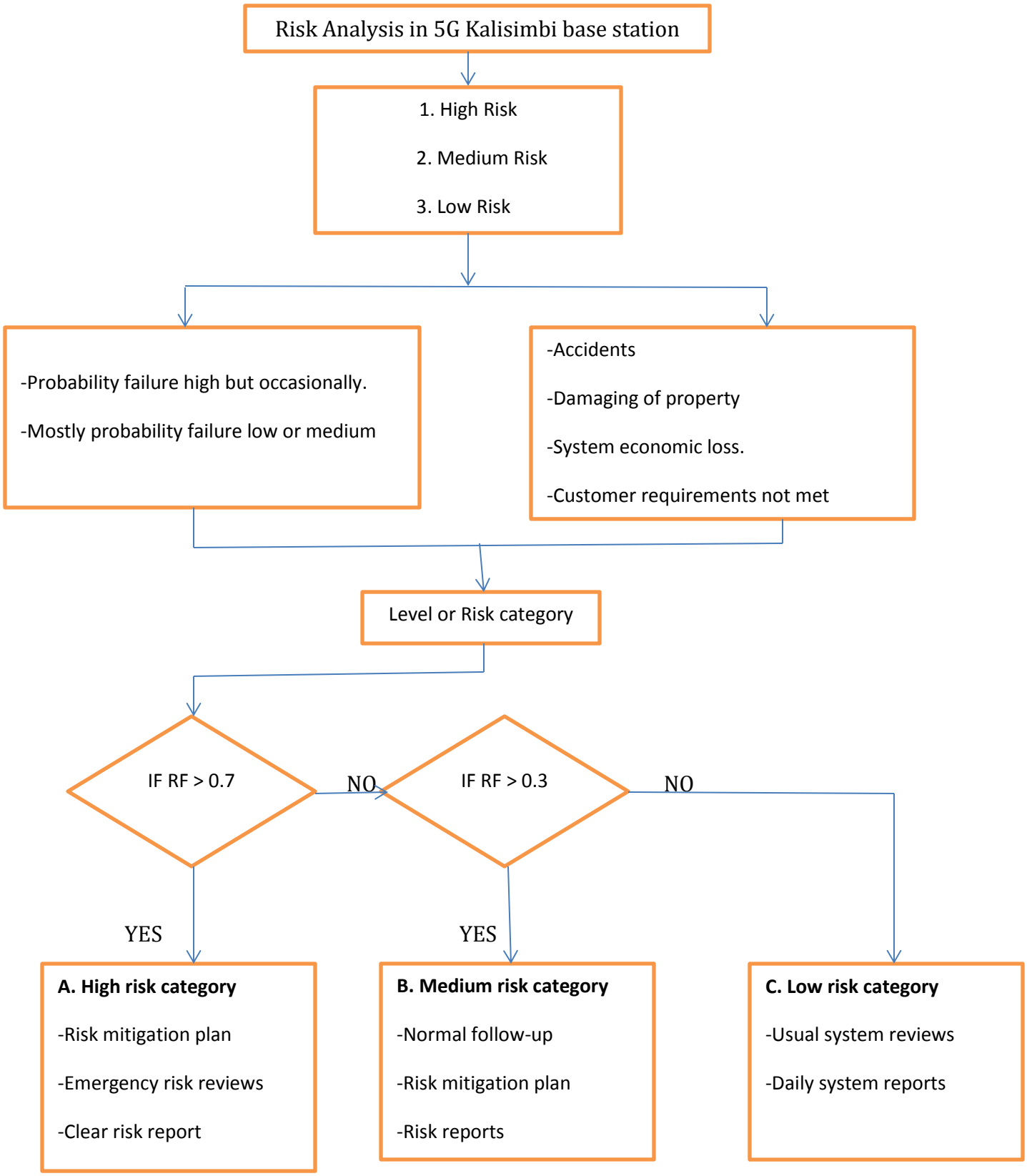
Standardize: 5G Kalisimbi base station has to be built up by components that are of standard quality. Every component has standard measures to be referred to either in being used to construct the system or in assistance. Standard qualities have to be applied at every part of the system component.

Sustain: This point is also crucial in the 5G Kalisimbi base station for the continuity of system development process. This ensures rapid progress and helps meet the schedules. More to that, this point also essential after the system is in operation to sustain it and continue working without failure for the given period of time.
For this to be achieved, it has to be a duty for every member on the project to beware of every kind of failure and notify it to be addressed before any severe damages. This also requires every employee to be conscious of every kind of risk and notify the rest in case of any.

11.4. RISK ANALYSIS AND REPORTING PROCEDURE

In Risk Analysis and reporting procedure for 5G Kalisimbi base station, probability of failure and consequence of failure variable tools which will be identified on the basis of technical performance measures, schedule or cost. These tools will be used to evaluate the three levels of risks. These levels will be classified as, high, medium or low. The two variable tools will be helping to identify the category of the risk due to having the Risk factor in the system. There will be standard classification of risks as low, medium or high. For all risks which have risk factors less than 0.3, these will be of low category. For all risks with risk factors greater than 0.3 but less than 0.7, these will be classified as Medium category. For all risks with risk factors greater than 0.7 will be classified as of high category of risks.

5G Kalisimbi base station Risk Analysis block diagram.



12. CONCLUSION

An updated delivery of quality technological services to Rwandan population is highly needed. This 5G Kalisimbi antenna base station will not only benefit Rwandan population but also people in the neighboring countries like Uganda,Kenya,Tanzania and the Democratic republic of Congo. Hence this technological system development will lead to the development of the region. It will also help them achieve 2020 goals and Millennium development goals.

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