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Manuscript Template and Style Guide (Horizon Mask Radio Frequency Interference Detector)

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Abstract

This project will describe the RF interference (RFI) measurements as performed at the SANSA Space Operations (SSO) located at Hartebeesthoek, South Africa at the site of the ground station. The aim of the measurements derived is to characterize the RF environment relevant to the site area. These measurements will be performed using an antenna that will rotate in Azimuth only from 0º to 360º and then 360º to 0º, scanning the horizon at a fixed elevation at a constant angular velocity. This setup will continuously monitor the RF environment by updating a live feed data base that will be readily available to the operator and a source of information for our clients and for our own records purposes. These records will be displayed in a form of a "water-fall graph" display. The information gathered will consist of the antenna angular direction, signals strength and timestamped at different intervals. This project will be designed to cater three different modes viz, 'Scan mode'; 'Detect mode' and 'Analyse mode'. In the Detect mode, we'll use data from the horizon Scan mode that may have yielded an interference signal above a certain threshold. In the Analyse mode we take that detected signal from the Detect mode and analyse the source of the signal. Moving the antenna at different parts of the site and detecting the same signal of interest at certain angles we could triangulate the source of the interference, if the source isn't within the site; and unnatural i.e. doesn't involve heavy rain or snow and solar flare radiation; we then could assist the Independent Communications Authority of South Africa (ICASA) by sending them the co-ordinates of the source which could be illegal. This project could also be used in other ground stations with similar satellite operation applications worldwide.

Keywords:
Interference
Radio Frequency
Polarization
Noise
Filter
Amplifier

Acronyms/Abbreviations

Azimuth – angle between the north vector and the perpendicular projection of the star down onto the horizon. Azimuth is usually measured in degrees (°).

dB – decibel - is a relative unit of measurement equal to one tenth of a bel (B).

dBi – dB Isotropic - is a unit of measurement used to quantify the gain of an antenna, indicating how effectively it transmits or receives signals compared to a theoretical isotropic antenna that radiates equally in all directions.

dBm – decibel-milliwatts - is a unit of power level expressed on a logarithmic scale, relative to one milliwatt.

Geostationary (GEO) – A satellite in a geostationary orbit is a spacecraft in the same revolution velocity as the earth. Example Satellite TV's dishes are fixed to one direction indicating that the transponder is in a geosynchronous orbit.

Hz – Hertz - measures the frequency of the cycle.

LHCP – Left Hand Circular Polarization.

LNA – Low-noise amplifier - an electronic component that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio.

Polarization – is a property of waves that can oscillate with more than one orientation. Electromagnetic waves such as light exhibit polarization, as do some other types of waves, such as gravitational waves.

RF – Radio Frequency, is any of the electromagnetic wave frequencies that lie in the range extending from around 3 kHz to 300 GHz, which include those frequencies used for communications or radar signals.

RFI – Radio Frequency Interference, when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction.

RHCP – Right Hand Circular Polarization.

RHCP/ LHCP – RHCP rotating clockwise and LHCP rotating counterclockwise when viewed along the direction of propagation.

SNR – Signal to noise ratio (also S/N, S/R, SNR and SN) - a measure that quantifies the strength of a desired signal relative to the strength of background noise, typically expressed in decibels (dB).

Terrestrial Networks – communication systems that rely on ground-based infrastructure like cell towers, fiber optic cables, and routing centres to transmit data and signals, encompassing both wired and wireless technologies like landlines, cellular networks, and Wi-Fi.

VSAT - Very Small Aperture Terminal - a type of satellite ground station that uses small, portable satellite dishes to transmit and receive data, providing connectivity in remote areas or where traditional terrestrial infrastructure is unavailable.

1 Chapter 1 - Introduction

1.1 Introduction

This chapter will summarize the need for this project and the importance of interference detection. The Satellite Users Interference Reduction Group (SUIRG) categorizes satellite communication interference into five main groups, these are:

- User Error
    a. Human Error
    b. Equipment Failure
- Cross-polarization Leakage
- Adjacent Satellites
- Deliberate Interference

1.2 Problem statement

The Independent Communications Authority of South Africa (ICASA) regulates the South African communications, broadcasting, and postal services sector, overseeing licensee compliance, developing regulations, managing the radio frequency spectrum, and protecting consumers of these services due to the small size of spacecraft signals that are easily dwarfed by interference. [6].

<u>The five main groups of RFI in satellite communication are:</u>

User Interference

Interference monitoring systems detect accidental errors, equipment malfunctions, and poor cable shielding, requiring significant manpower and time. They also detect leaking RF, damaged or unconnected cabling or equipment.

Cross-polarization Interference

Interfering services can cause issues like incompatible modulation types, poorly aligned antennas, and lack of training/experience in uplink operators, leading to unusable capacity and time-consuming equipment and training.

Adjacent Satellite Interference

Interference between satellites, often accidental due to operator error or poor inter-system coordination, is becoming more prevalent as two degree spacing increases in the geostationary arc. [3].

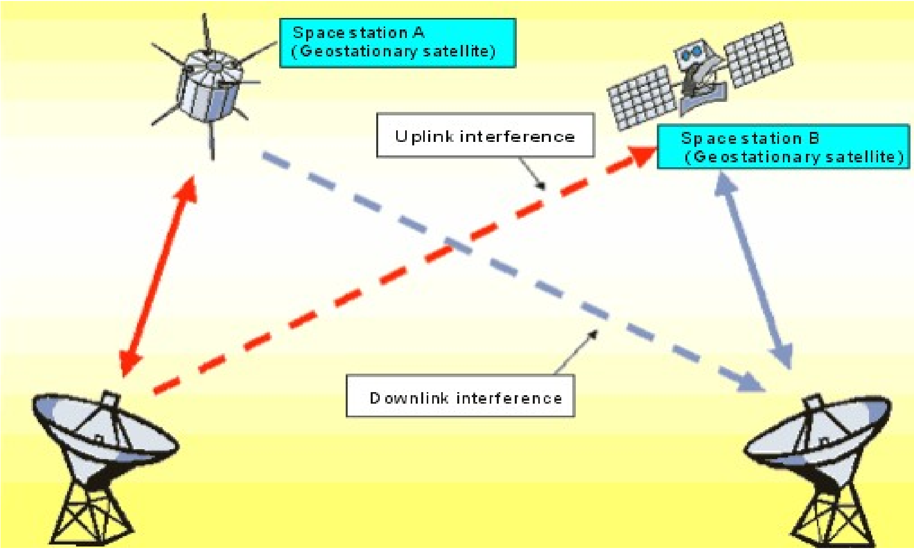


Figure 1.1: Coordination of satellite networks that can cause interference.

Satellite operators seek non-interference spectrum use, consuming significant manpower and time, leading to spectrum loss and revenue loss.

Deliberate interference

Geopolitically motivated interference is easy to locate but nearly impossible to remove without political intervention, as illustrated in Figure 1.2.

Figure 1.2: Example of a commercially available GPS jammer.

The project may face additional interference from its own site due to broken cables leaking RF, which may be due to unplugged or unconnected equipment. [1].

Figure 1.3 illustrates how interferences from different groups can cause an antenna to auto-track on false signals, if the false signal strength masks the desired signal from the spacecraft.

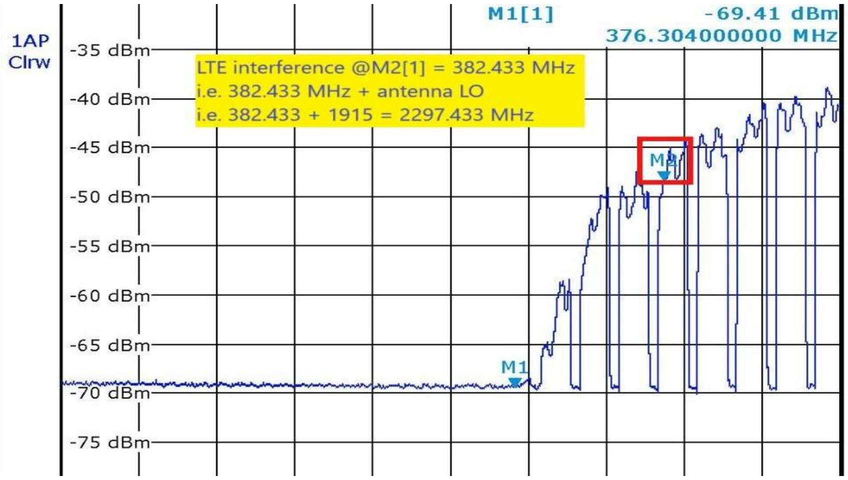


Figure 1.3: LTE interference of ~20dBm at Marker M2 as compared to Marker M1 at the noise floor.

SANSA Space Operations will detect and report illegal signals from unlicensed operators to ICASA, providing additional information on direction, frequency, signal strength, and timestamp to help locate and stop perpetrators.

Scanning of the horizon

The antenna's mechanism rotates from 0º to 360º and then 360º to 0º to prevent cable wrapping, with software included to account for angular rotation inertia.

The antenna could jam, damaging the motor. To prevent this, a current sensing circuit using a ZXCT1009 diode chip can scale voltage to the microcontroller within its operating voltage.

1.3 User requirement specification

The user must be computer literate, familiar with the antenna's operation, interpret results, communicate with clients, and be familiar with preventative maintenance of the rotary equipment.

1.4 Study objectives

The Antenna Control Unit (ACU) operates by regulating the frequency and phase of signals transmitted, while a feedback control loop effectively manages the effects of interference on satellite communications.

The radio frequency spectrum is crucial for space activities, but its limited natural resource can lead to unintentional interference (RFI) due to increased terrestrial and space users. Management of the RF spectrum is complex, with national and international entities oversight. RFI poses a challenge for space sustainability and security. [1].

1.5 Importance and benefits of the study

SANSA Space Operations (SSO) is a global ground station for communication between satellites and ground stations. It uses electromagnetic spectrum to observe, control, monitor, and collect information from spacecraft. This project will benefit SSO and all ground stations worldwide by enhancing their RF environment for TT&C efficiency.

Daily, we use computers, mobile phones, and travel for work or pleasure, watching TV, and checking weather without considering their functionality or potential discontinuation.

Governments and organizations invest in space science, technology, and engineering, enabling the development of essential services like cell phones, internet, GPS, satellite TV, ATMs, meteorological forecasting, and safe travel. [2].

Earth observation aids in better planning infrastructure, resource management, disaster mitigation, agricultural concerns, and disease monitoring, ensuring better planning and management of our planet.

Monitoring solar activity is crucial for Earth's safety, as severe flares could lead to satellite loss, grounded vessels, power grid disruptions, and emergency rescue services, requiring backup systems for continuity.

Loss of space capabilities can have long-term impacts on daily life, particularly when backup systems are relied upon to perform current functions.

1.6 Budget

The initial budget for the project includes a Spectrum Analyser, which primarily focuses on interference signal strength. The Analyser is chosen based on the user's frequency range, covering the S-band frequency range (2.2-2.4 GHz). It has a wider operating range (850 MHz – 26.5 GHz) and can capture signal data for data acquisition.

The operator will control the antenna using a microcontroller, such as Arduino Uno or NI LabVIEW, which is mostly automated but allows the operator to point the antenna to specific positions.

The controller uses a digital potentiometer to adjust the voltage to the H-Bridge and control the antenna's forward and reverse Azimuth movement, with 129 steps for accuracy.

Table 1-1 Budget of the horizon mask detector project.

Components	Cost [R]
Antenna *2 (for vertical and horizontal polarizations)	3 000.00
NEMA 17 Stepper motor	300.00
Coaxial Cabling (100 meters) and connector	3 635.00
Down converter: mixer, Local oscillator and Band pass filter	1 716.00
Spectrum Analyser	300 000.00
Arduino Uno SMD Rev3	378.55
Transistor (ZXCT1009FTA)	13.79
Personal Computer	5 000.00
2000mm x 1000mm x 3mm thick - Aluminium sheet	1 200.00
15 VDC 1.7 A power supply	150.00
Digital potentiometer	14.00
L293D H-bridge	15.00
Total component cost:	R315 412.34

2 Chapter 2 – Material and methods

2.1 Introduction

This chapter explores the significance of interference detection, and the research conducted on systems that effectively implement this need.

Satellite telecom faces interference from ground-based transmitters, causing service impairment and degradation. A tool to quickly identify and remove unwanted signals is needed to protect on-orbit assets and reduce illegal space use.

2.2 Literature review

The rapid increase in interference, piracy, and jamming, coupled with the growing number of satellites and VSAT terminals, is a major issue affecting satellite operators' quality of service. [4].

This paragraph delves into various interference solution methods:

2.2.1 Interference Removal and Noise Reduction

CSIR™ (Communications Signal Interference Remover) is an application that real-timely removes interferences from a communications carrier, improving its signal-to-noise ratio, as demonstrated in the Glowlink Model GS380X Interference Removal System. [4].

The Glowlink GS380X Interference Removal System is a real-time technology that removes interferences from communication signals before they reach the receiver, ensuring no adverse effects on the demodulation part of the channel. It is used in airborne, satellite, terrestrial, and shipboard communications, requiring only approximate carrier center frequency, bandwidth, and modulation information. [4].

Figure 2.1: **GS380X Streaming Interference Removal Improves Receive Performance.**

2.2.2 Satellite Interference Geolocation

Satellite communications are susceptible to interferences, causing transponders to fail. Finding the source and locating rogue transmissions is crucial for resolution, especially in intentional or equipment fault cases. [5].

CSIR™ technology removes masking carriers on adjacent satellites, exposing underlying interference and its replica for accurate geolocation, overcoming limitations of interference-masked systems. [5].

The Glowlink GS380L Geolocation Signal Enhancement System enhances interference geolocation by removing obstructing carriers. When combined with the Glowlink Model 8000 Geolocation System, it improves performance by 70+ dB and offers a net processing gain of over 142+ dB, ensuring successful interference geolocation operations. [4].

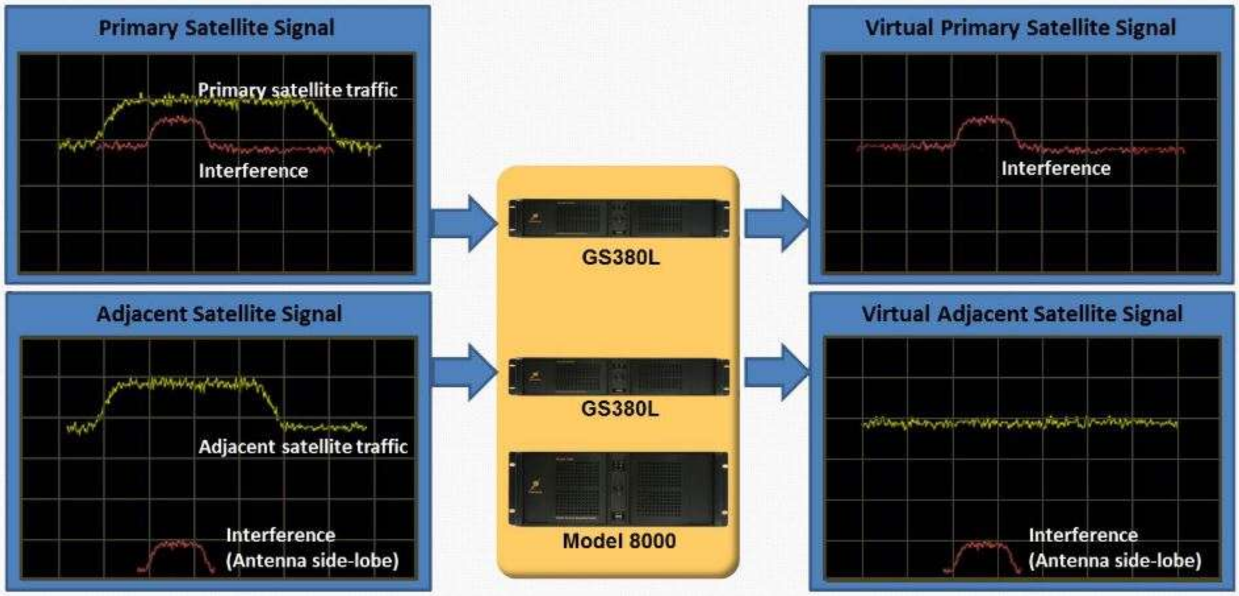


Figure 2.2: GS380L Removes Obstructing Signals to Enhance Geolocation Performance.

2.2.3 Signal Reception, Monitoring and Analysis

CSIR™ technology is used in signal reception, monitoring, and analysis to separate composite communication signals, preserving fidelity of overlapping carriers. This is useful for intentionally overlapping signals in satellite communications.

The Glowlink GS380S Signal Separator System, when used with a Glowlink Model 1000x2 spectrum monitoring system, separates two overlapping communications carriers in real time, maintaining signal fidelity. [4]

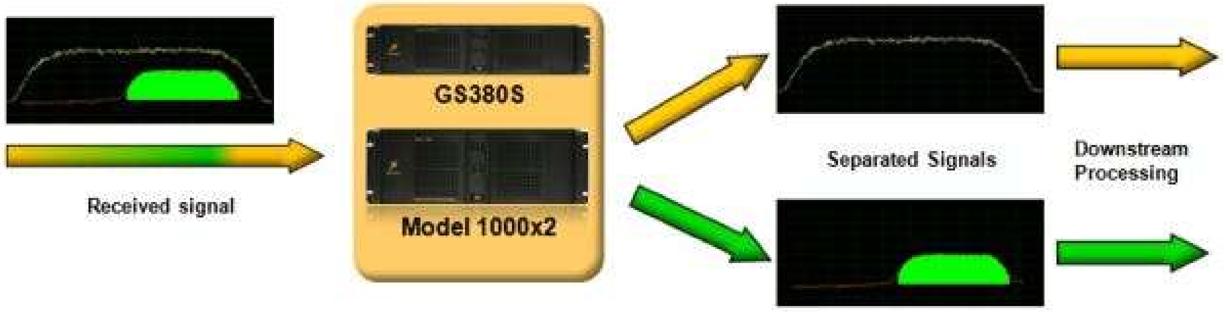


Figure 2.3: GS380S Separates Signals for Downstream Processing.

2.3 Proposed practical design or strategy

<u>The RF design overview:</u>

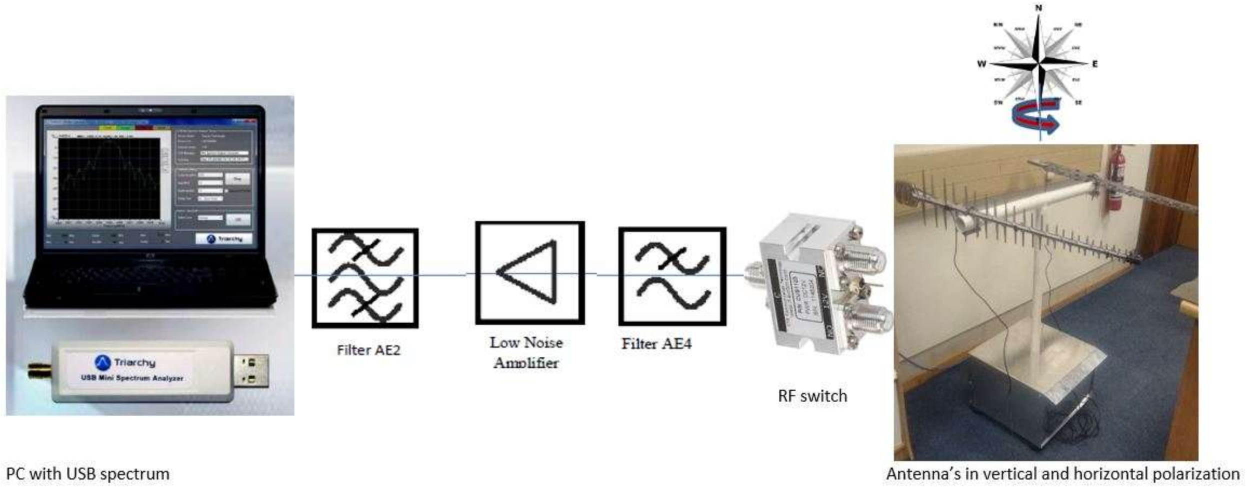


Figure 2.4: Simple block diagram illustrating the interference detection procedure.

<u>The design will mainly be focused on the antenna Azimuth rotation.</u>

The antenna will rotate Azimuth from 0º to 360º and then 360º to 0º to prevent cable wrapping, utilizing software limitations within the program.

The system consists of two parts: a field part with an antenna and band pass filters, and a separate room for operator access. It includes a spectrum analyzer, database computer, warning system, filter, and control system for the antenna. The system aims to scan, detect, and analyze interference signals.

<u>The electrical design overview:</u>

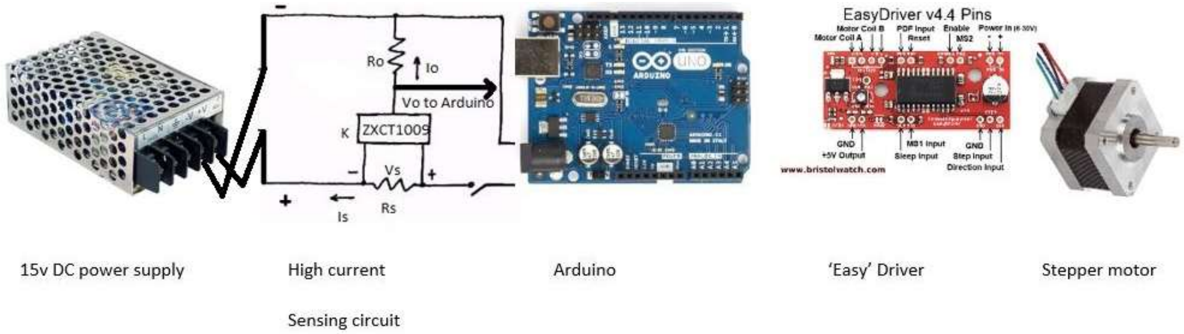


Figure 2.5: Simple block diagram illustrating source connection.

<u>Physical movement of the antenna:</u>

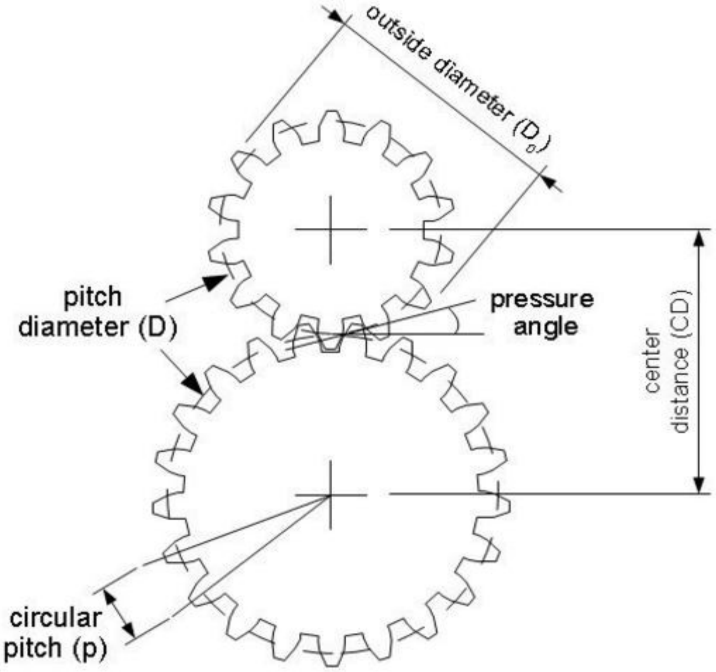
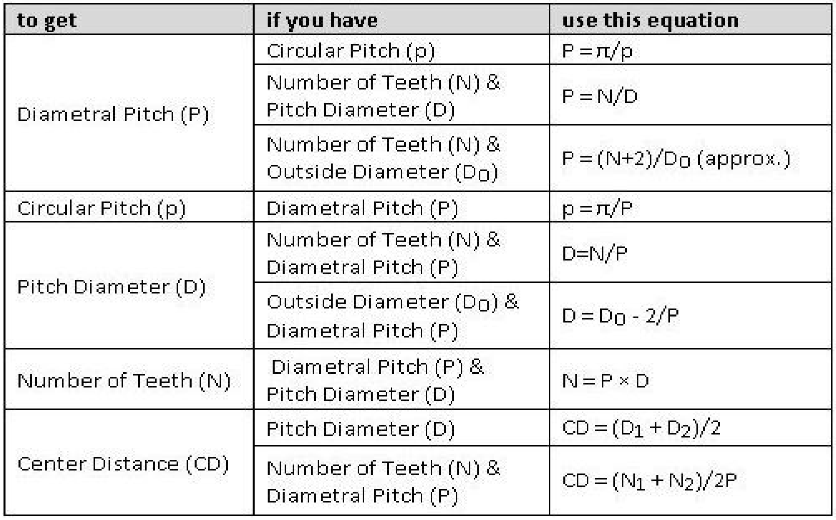


Figure 2.6: Gear design parameters.

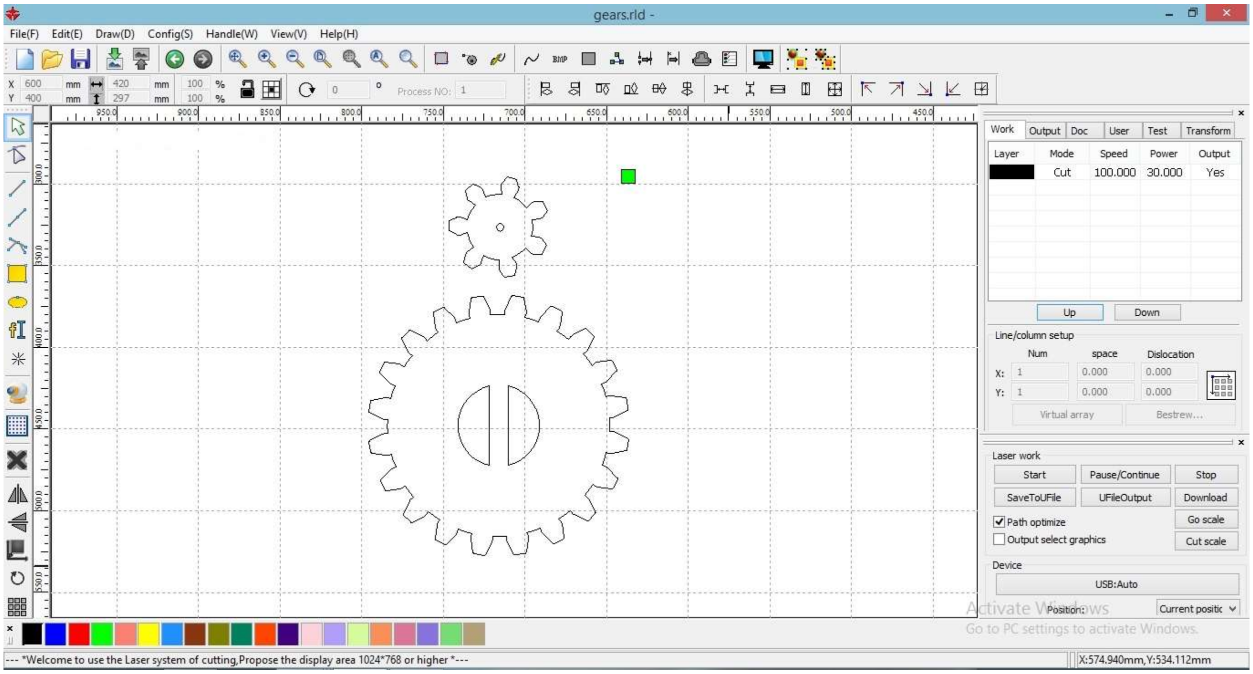
Figure 2.6 provides a summary of the parameters used in gear design, while Table 2-1 provides the formulae for these parameters. [8].

Table 2-1 Gear design parameter formulae.



to get	if you have	use this equation
Diametral Pitch (P)	Circular Pitch (p)	$P = \pi/p$
	Number of Teeth (N) & Pitch Diameter (D)	$P = N/D$
	Number of Teeth (N) & Outside Diameter (D_O)	$P = (N+2)/D_O$ (approx.)
Circular Pitch (p)	Diametral Pitch (P)	$p = \pi/P$
Pitch Diameter (D)	Number of Teeth (N) & Diametral Pitch (P)	$D=N/P$
	Outside Diameter (D_O) & Diametral Pitch (P)	$D = D_O - 2/P$
Number of Teeth (N)	Diametral Pitch (P) & Pitch Diameter (D)	$N = P \times D$
Center Distance (CD)	Pitch Diameter (D)	$CD = (D_1 + D_2)/2$
	Number of Teeth (N) & Diametral Pitch (P)	$CD = (N_1 + N_2)/2P$

Figure 2.7 shows designed gears with a 1:2.666 ratio, increasing shaft gear torque output by 40% and increasing motor load capacity, as per the specifications of the NEMA 17 Stepper motor.



X 600 mm 420 mm 100 %
Y 400 mm 297 mm 100 %
0 °
Process NO: 1

Layer	Mode	Speed	Power	Output
■	Cut	100.000	30.000	Yes

Line/column setup

	Num	space	Dislocation
X:	1	0.000	0.000
Y:	1	0.000	0.000

☑ Path optimize
☐ Output select graphics
Position: Current positic

--- "Welcome to use the Laser system of cutting,Propose the display area 1024*768 or higher "---
X:574.940mm,Y:534.112mm

Figure 2.7: Design of motor gear and shaft gear.

The Rotman Lens Design Software generated an RLD file, which was then cut using a 9mm width laser cut machine.

2.4 Product specifications or requirements

In Table 2-1 below we have the necessary requirements for the hardware illustrated in Figure 2.1.

Table 2-1 Hardware list as per Figure 2.4.

No	Item	Model	Serial number
1	LPDA Antennas	A-LPDA-0092	
2	Filters	LORCH 11EZ3-2300/A200-S	AE 2/ AE 4
3	LNA	Miteq JS2-02200240-05-10P	710408
4	Triarchy Tech USB Mini Spectrum Analyser	TSA6G1	CN61800890

A-LPDA-0092

The antenna, with its 694 - 3000 MHz band operator and 12 dBi high-gain performance, is ideal for extreme weather environments and signal challenges, and will be installed horizontally and vertically.

Low Noise Amplifier (LNA)

The LNA specifications shown below in Table 2-2.

Table 2-2 Amplifier LNA specifications.

Freq (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	Output Power @ 1 dB COMP. (dBm, Min.)	VSWR IN/OUT	DC POWER @ +15 V (mA, Nom.)
2.2–2.4	32	0.5	0.5	10	1.8:1	195

<u>Spectrum Analyser</u>

The Triarchy Tech USB Mini Spectrum Analyser covers a wide frequency range (1 MHz - 5 GHz) and a maximum bandwidth of 500 kHz for analysis.

3 Chapter 3 – Theory and calculation

3.1 Introduction

This chapter focuses on the executing phase, where we assembled pieces by conducting separate equipment tests and observing the RF environment on site.

3.2 Design or development of product / strategy

3.2.1 Surveying of the site RF environment

The site was surveyed using an antenna, fed through a filter, LNA, and spectrum analyzer. Measurements were taken in 45⁰ increments, resulting in 64 measurements for each of the two polarisations, due to the narrow radiation pattern of the antenna.

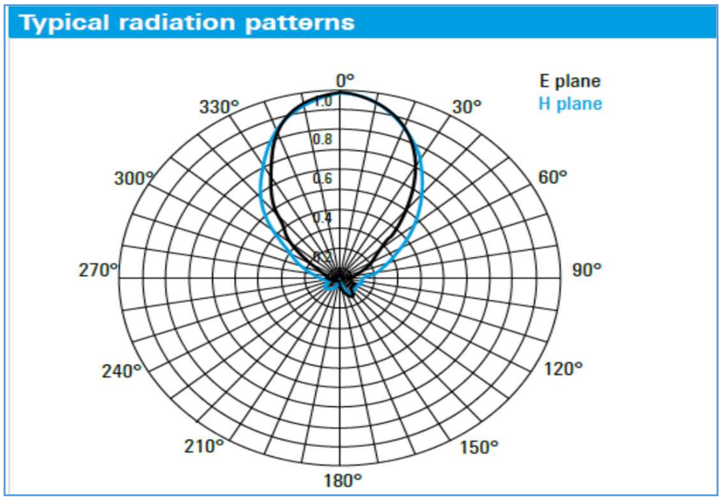


Figure 3.1: Antenna radiation pattern.

The results were adjusted for losses and gains of each measurement element and further adjusted relative to a 1 square meter isotropic antenna.

Low levels in the measured data led to the signal analyzer's clocking frequency harmonics being picked up, which could be corrected by adjusting the measurement setup and repeating the survey.

The clock noise was verified by pointing the antenna directly at the instrument with the resulting clocking noise, as shown in Figure 3.2.

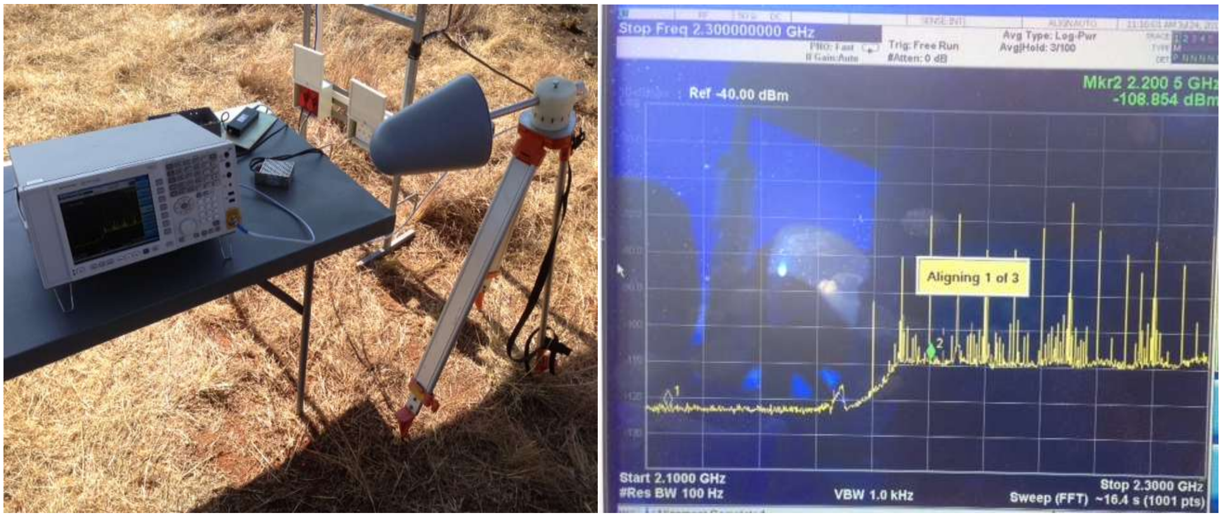


Figure 3.2: Experiment setup showing clocking noise of signal analyser.

The antenna was pointed away from the signal analyser, approximately 2 meters away, which was the maximum viable distance given the cable lengths used. The resultant measurement is shown in Figure 3.3

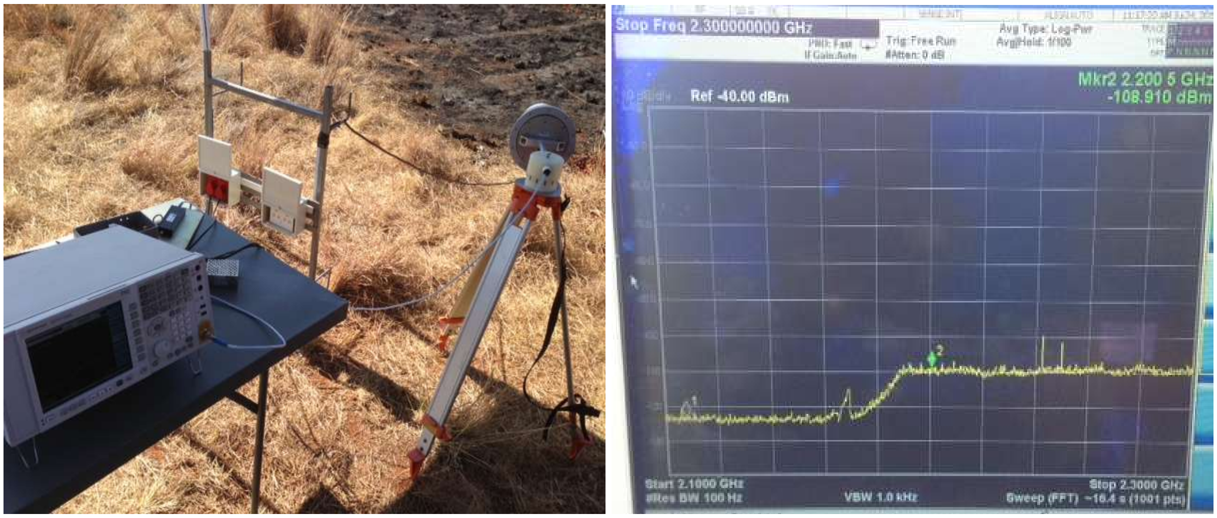


Figure 3.3: Reducing clock noise to negligible levels.

3.2.2 RF design component overview

Figure 2.4 displays a test setup where tests were conducted:

The LPDA multiband antenna

Refer to Appendix A.2.

The RF switch

The Arduino program toggles a voltage, changing the polarity of the downlink stream to the spectrum analyser after

360-degree Azimuth angular rotation, which is documented in a continuously updating database on the PC.

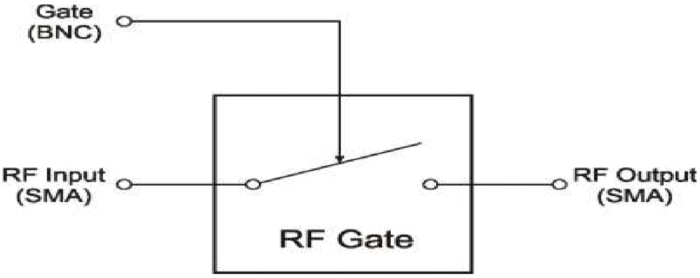


Figure 3.6: RF switching schematic.

The low noise amplifier (LNA)

The device detects amplified small signals that can be easily observed and documented in data acquisition (DAQ).

Figure 3.7: Miteq low noise amplifier.

Band Pass Filter

The S- Band filter, which restricts the frequency range of frequencies received from the antenna, permits only 2.2-2.4 GHz frequencies to pass through to the spectrum analyzer.

Figure 3.8: S-Band band pass filter.

The Mini USB spectrum analyser

The software-based spectrum analyzer is small, mobile, and cheaper than regular analyzers, directly interfaced with computers for easy data acquisition (DAQ).

Figure 3.9: Triarchy Mini USB spectrum analyser.

3.2.3 Electrical design overview

Figure 2.5 displays a test setup, while Figure 3.10 provides a schematic of component installation.

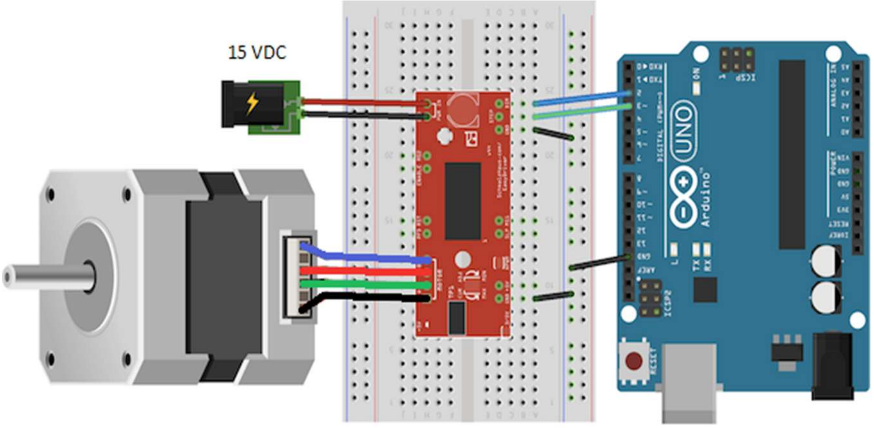


Figure 3.10: Schematic of the electrical connection of the motor with driver and controller.

Stepper motor

The stepper motor is a bi-polar (4 wire) motor with two coils, 'coil A' and 'coil B', energized strategically based on driver and step size, causing the rotor to move in the desired direction, making it suitable for open loop control strategies.

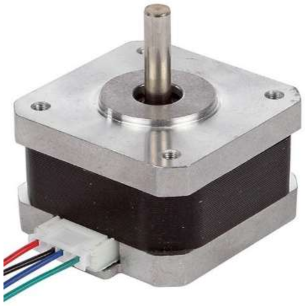


Figure 3.11: Bi-polar NEMA-17 stepper motor.

Easy driver

This stepper motor driver adjusts current, controlling speed via an Arduino microcontroller, by programming a delay period for the toggling sequence of the motor coils.

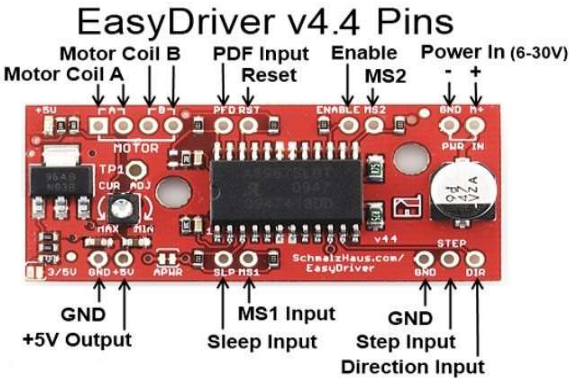


Figure 3.12: Stepper motor Easy Driver.

3.3 Implementation of product / strategy

The project requires checking the waterproofing of the aluminium box, applying silicon, if necessary, periodically grease the antenna shaft, and ensuring the insulation of brackets used to hold antennas along the shaft.

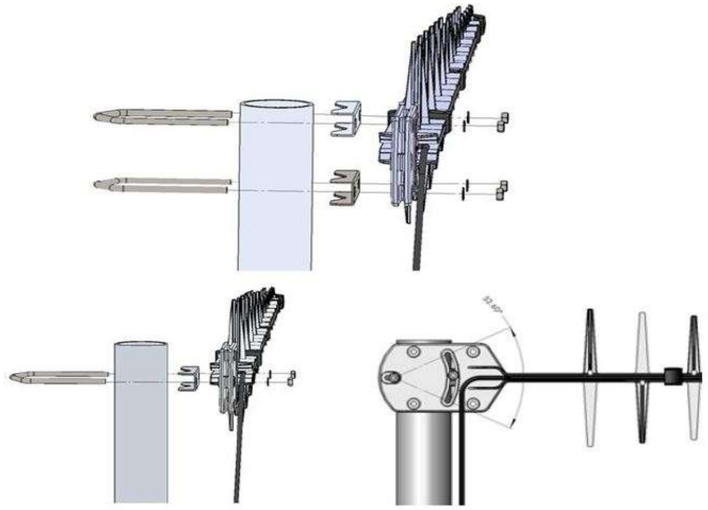


Figure 3.13: Antenna installation.

3.4 Testing procedure

3.4.1 Antenna testing on site

We manually move the antenna to test it in both polarisations on site, following the procedure shown in Figure 2.4.

Large signals were detected within the frequency band of interest, as shown in Figure 3.15, received at one of our DORIS antennas. Figure 3.16 displays the signal received in horizontal polarization.

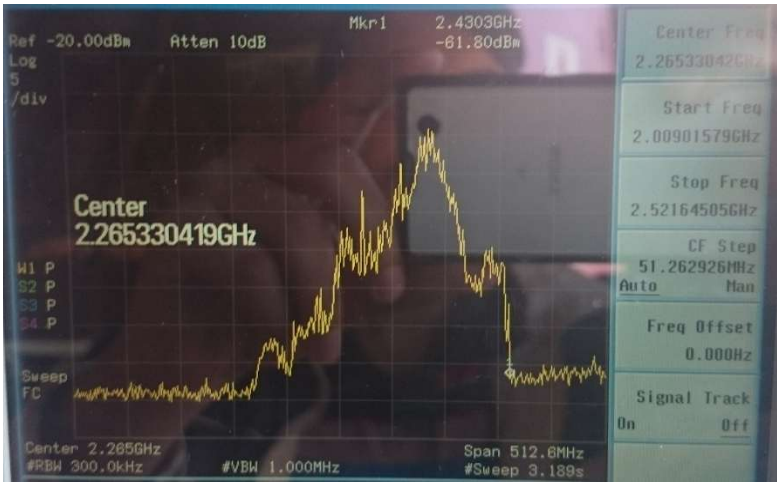


Figure 3.14: Spectrum screenshot of DORIS antenna vertical pol signal reception.

Figure 3.15: Spectrum screenshot of DORIS antenna horizontal pol signal reception.

The experiment reveals uncertainty in our satellite tracking strategy due to the DORIS antenna and other locations, prompting evasive action.

3.4.2 Testing of the motor

The NEMA 17 Stepper motor was tested with a 5-volt LED connected to coils A and B, indicating its functionality when a back EMF was generated.

3.5 Necessary changes encountered

We replaced a large bearing with a smaller one, adjusted motor and antenna shaft gears, and removed the joystick to enable the antenna to scan the horizon independently in 'Scan mode'.

4 Chapter 4 - Results

4.1 Introduction

This chapter focuses on controlling and monitoring antenna movement using 'Scan' and 'Analyse' modes and logging data using 'Coolterm' and 'LabVIEW' software. Coolterm time stamps angles using Arduino code, while LabVIEW interfaces with a spectrum analyzer, obtaining a trace in 'txt' format.

4.2 Results of the tested product / procedure

The 'Coolterm' software is used to log data at a rate determined by the antenna's slew rate:

Slew rate = (total angle through which antenna rotates)/ (total time of the manoeuvre).

The antenna was tested at a slew rate of 9.645 degree/sec, with a 2.666:1 ratio between the motor gear and shaft gear. The angle of the shaft gear was logged, revealing a good resolution of 0.2 degrees.

Table 4-1 Sample data time stamped with Azimuth angles.

YYYY-MM-DD HH:MM:SS	AZIMUTH (degrees)
2016-11-14 10:19:50	91.01
2016-11-14 10:19:50	91.23
2016-11-14 10:19:50	91.45
2016-11-14 10:19:50	91.67
2016-11-14 10:19:50	91.89
2016-11-14 10:19:50	92.11
2016-11-14 10:19:50	92.32
2016-11-14 10:19:50	92.54

We use LabVIEW software to analyze signals received at various frequencies, as illustrated in Table 4-2.

We integrated NI-VISA and NI-MAX software to create a spectrum analyzer interface, ensuring communication with the NI-MAX software through the command "READ:SAN?".

LabVIEW was used to create a block diagram 'vi', as illustrated in Figure 4.1, which provided trace data as shown in Table 4-2.

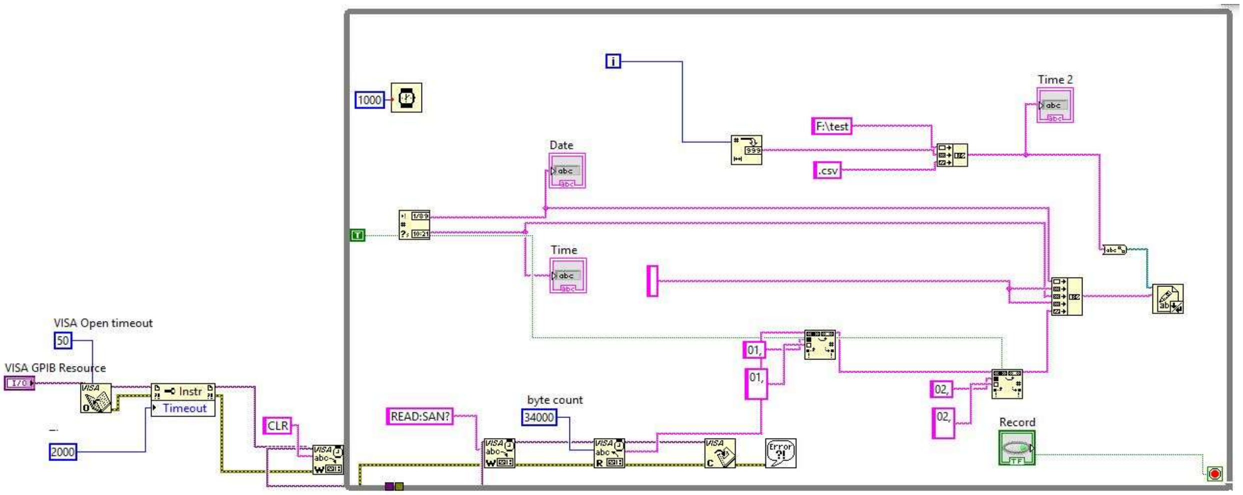


Figure 4.1: Block diagram of visual interface using LabVIEW.

Table 4-2 Sample data of a trace with signals logged at different frequencies.

FREQUENCY (GHz)	SIGNAL (dBm)
2.100000000E+09	-8.158344269E+01
2.105000000E+09	-9.029610443E+01
2.110000000E+09	-8.083306122E+01
2.115000000E+09	-9.259277344E+01
2.120000000E+09	-8.127179718E+01
2.125000000E+09	-8.768190765E+01
2.130000000E+09	-8.162822723E+01
2.135000000E+09	-9.065912628E+01

The trace sample in Table 4-2 shows low signal magnitude and no interferences. Data was recorded from a timestamp-named txt file, allowing analysis of angle with signals based on frequencies.

4.3 Comparison of results vs. requirements

Antenna testing on site revealed an issue with DORIS signals, affecting support. Resolution is being worked on to prevent interference from these signals, as per Table 4-3.

Table 4-3 Sample received from DORIS antenna on site.

FREQUENCY (GHz)	SIGNAL (dBm)
2.500000000E+09	-4.058359819E+01
2.505000000E+09	-3.848465105E+01
2.510000000E+09	-4.548440844E+01
2.515000000E+09	-3.808451615E+01
2.520000000E+09	-3.804412051E+01
2.525000000E+09	-3.084108458E+01
2.530000000E+09	-4.846165562E+01
2.535000000E+09	-5.816515612E+01

A signal generator was used to transmit a signal to the project, measuring its reception at a 2.3 GHz frequency for accuracy.

FREQUENCY 2.300 000 000 00 GHz

AMPLITUDE -30.00 dBm

Figure 4.2: Signal generator set within the band of interest.

The comparisons are presented in Tables 4-4 below.

Table 4-4 Sample data received from the collimation tower generated by a signal generator.

FREQUENCY (GHz)	SIGNAL (dBm)
2.275000000E+09	-8.846516054E+01
2.280000000E+09	-8.916516051E+01
2.285000000E+09	-8.083304845E+01
2.29000000E+09	-9.168445179E+01
2.295000000E+09	-8.127177818E+01
2.300000000E+09	-3.168190765E+01
2.305000000E+09	-8.248450841E+01
2.31000000E+09	-9.084948410E+01

The intended signal received at 31.6 dBm at 2.3 GHz, with a relative error of 5.33% due to slight signal loss from a 2 km away collimation tower.

5 Chapter 5 - Discussion

5.1 Introduction

This chapter focuses on the project closure phase, evaluating its successes and drawbacks, and providing recommendations for improvement.

5.2 Conclusions and recommendations

A 'down time' is foreseeable for calibrating the spectrum analyzer and may be necessary for mechanical wear, such as motor, bearing, and gears, which can be detected by logging significant angle offsets.

Monthly maintenance is required to ensure proper greasing of bearings, waterproofing of aluminium housing with silicon, and full operation of rack fans to maintain temperature.

The study merges text files to create a single document, capturing a live "waterfall" graphical view of data, making it easier to read and demonstrate in presentations.

The current band pass filter can be replaced to receive data from another band, but LDPA antennas are limited within the RF spectrum, potentially necessitating additional antennas.

5.3 Financial cost and time evaluation

Table 1-1 compares with final budget in Table 5-1, revealing necessary changes, including removal of on-site components like coaxial cabling, personal computer, aluminium sheet, and 15Vdc power supply.

The Agilent spectrum analyser was replaced with the Triarchy Tech Mini USB spectrum analyser due to its portability and sufficient technical specifications. The Agilent spectrum analyser had a larger frequency range and was cheaper. The L293D H-bridge IC was replaced with the Stepper Motor Easy driver for ease of implantation and interfacing. Arduino required less coding for future changes, making the project more accurate and cost-effective.

Table 5-2 Final budget.

Components	Cost [R]
Antenna *2 (for vertical and horizontal polarizations)	3 400.00
NEMA 17 Stepper motor	178.00
Down converter: mixer, Local oscillator and Band pass filter	1 716.00
Triarchy Tech Mini USB spectrum analyser	16 000.00
Arduino Uno SMD Rev3 starter kit	670.50
Transistor (ZXCT1009FTA)	13.79
Stepper motor Easy driver	110.00
Total component cost:	R22 088.29

The Gantt chart in Appendix A.1 outlines the most time-consuming tasks for the project, including obtaining the Triarchy Mini USB spectrum analyzer, overcoming hurdles due to unfavourable weather conditions, and using in-house equipment. The project also required thicker gears for reliable antenna slew rate due to changes in the spectrum analyzer, and laser cutting four additional gears with perspects glue.

5.4 Proposed further study

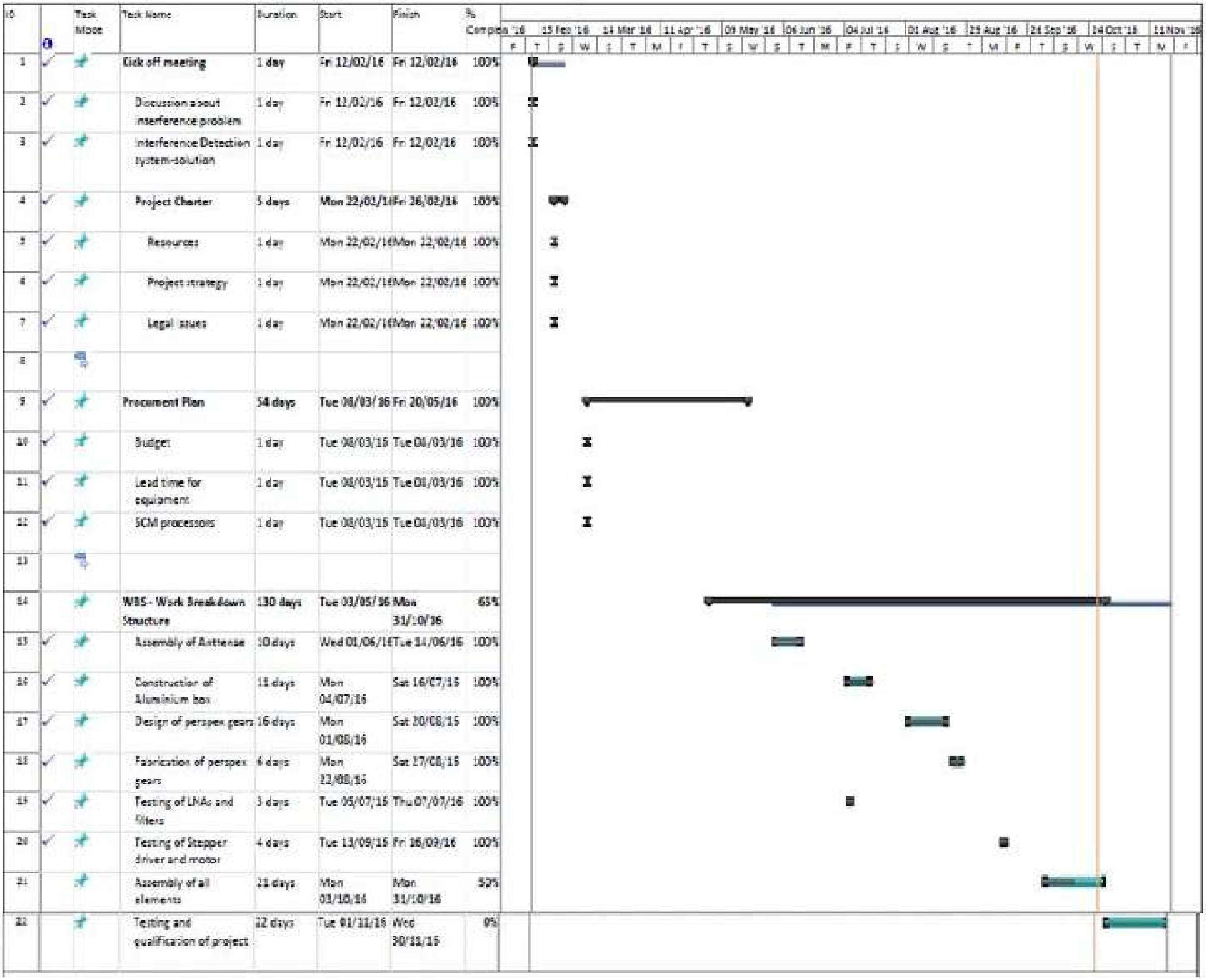
A proposal to add a secondary axis to the antenna's mechanical movement, allowing simultaneous Azimuth and Elevation angles, could simulate satellite trajectories and detect interference using Two Line Elements (TLEs), potentially causing false signals.

6. Conclusions

The project aimed to expand receive link budget components for S-Band interferers and accommodate other bands, particularly C-Band, due to 5G technologies and potential interference, using a wider band antenna, filters, and spectrum analyzer.

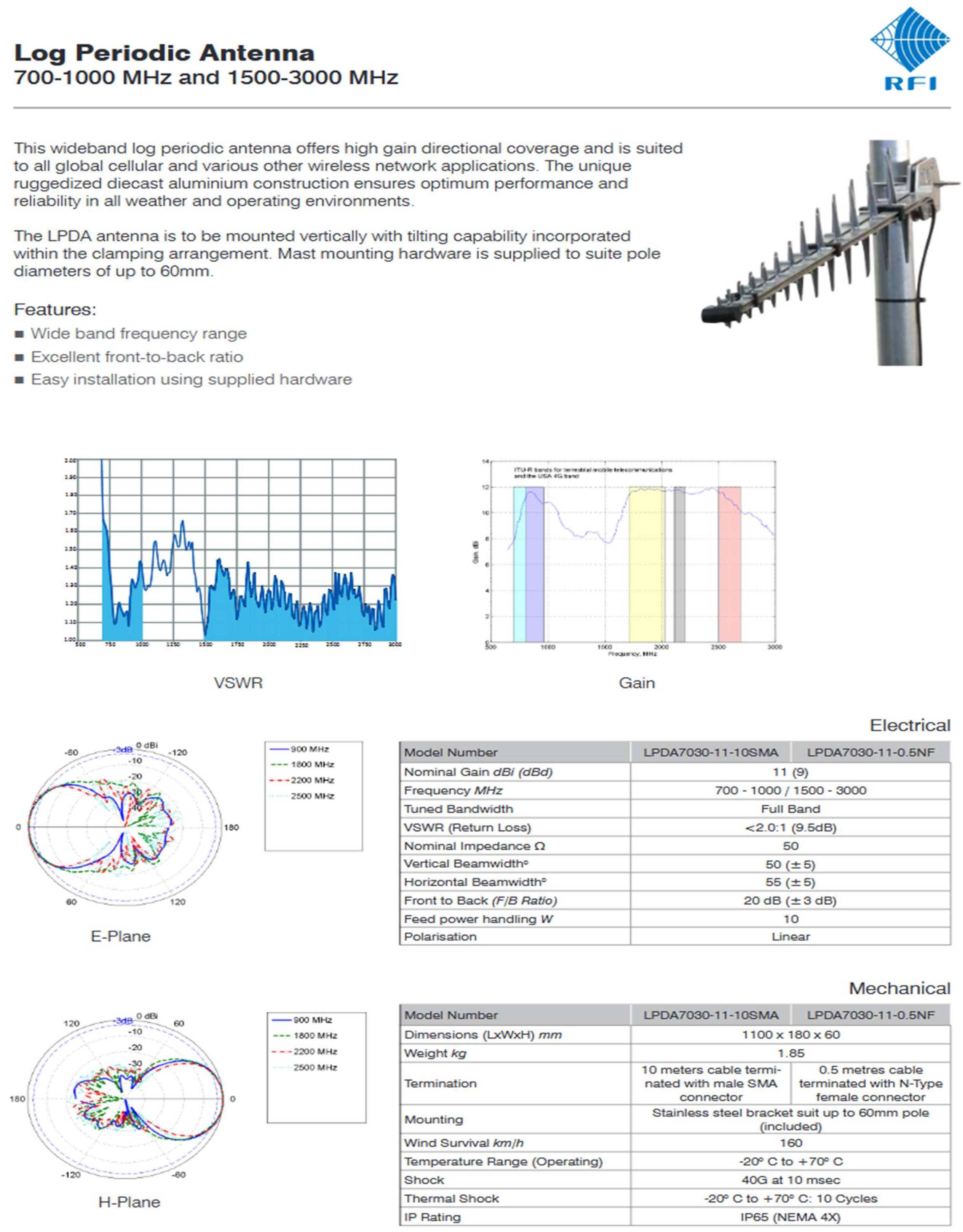
Acknowledgements
With colleagues of SANSA Space Operations team for their input towards this project.

Appendix A.1 Final Gantt chart



ID		Task Mode	Task Name	Duration	Start	Finish	% Complete
1	✓		Kick off meeting	1 day	Fri 12/02/16	Fri 12/02/16	100%
2	✓		Discussion about interference problem	1 day	Fri 12/02/16	Fri 12/02/16	100%
3	✓		Interference Detection system-solution	1 day	Fri 12/02/16	Fri 12/02/16	100%
4	✓		Project Charter	5 days	Mon 22/02/16	Fri 26/02/16	100%
5	✓		Resources	1 day	Mon 22/02/16	Mon 22/02/16	100%
6	✓		Project strategy	1 day	Mon 22/02/16	Mon 22/02/16	100%
7	✓		Legal issues	1 day	Mon 22/02/16	Mon 22/02/16	100%
8							
9	✓		Procurement Plan	54 days	Tue 08/03/16	Fri 20/05/16	100%
10	✓		Budget	1 day	Tue 08/03/16	Tue 08/03/16	100%
11	✓		Lead time for equipment	1 day	Tue 08/03/16	Tue 08/03/16	100%
12	✓		SCM processors	1 day	Tue 08/03/16	Tue 08/03/16	100%
13							
14			WBS - Work Breakdown Structure	130 days	Tue 03/05/16	Mon 31/10/16	65%
15	✓		Assembly of Antennae	10 days	Wed 01/06/16	Tue 14/06/16	100%
16	✓		Construction of Aluminium box	11 days	Mon 04/07/16	Sat 16/07/16	100%
17	✓		Design of perspex gears	16 days	Mon 01/08/16	Sat 20/08/16	100%
18	✓		Fabrication of perspex gears	6 days	Mon 22/08/16	Sat 27/08/16	100%
19	✓		Testing of LNAs and filters	3 days	Tue 05/07/16	Thu 07/07/16	100%
20	✓		Testing of Stepper driver and motor	4 days	Tue 13/09/16	Fri 16/09/16	100%
21			Assembly of all elements	21 days	Mon 03/10/16	Mon 31/10/16	50%
22			Testing and qualification of project	22 days	Tue 01/11/16	Wed 30/11/16	0%

Appendix A.2 Datasheets



Log Periodic Antenna
700-1000 MHz and 1500-3000 MHz

This wideband log periodic antenna offers high gain directional coverage and is suited to all global cellular and various other wireless network applications. The unique ruggedized diecast aluminium construction ensures optimum performance and reliability in all weather and operating environments.

The LPDA antenna is to be mounted vertically with tilting capability incorporated within the clamping arrangement. Mast mounting hardware is supplied to suite pole diameters of up to 60mm.

Features:
- Wide band frequency range
- Excellent front-to-back ratio
- Easy installation using supplied hardware

VSWR

Gain

E-Plane

Electrical

Model Number	LPDA7030-11-10SMA	LPDA7030-11-0.5NF
Nominal Gain *dBi (dBd)*	11 (9)	
Frequency *MHz*	700 - 1000 / 1500 - 3000	
Tuned Bandwidth	Full Band	
VSWR (Return Loss)	<2.0:1 (9.5dB)	
Nominal Impedance Ω	50	
Vertical Beamwidth°	50 (± 5)	
Horizontal Beamwidth°	55 (± 5)	
Front to Back *(F/B Ratio)*	20 dB (± 3 dB)	
Feed power handling *W*	10	
Polarisation	Linear	

H-Plane

Mechanical

Model Number	LPDA7030-11-10SMA	LPDA7030-11-0.5NF
Dimensions (LxWxH) *mm*	1100 x 180 x 60	
Weight *kg*	1.85	
Termination	10 meters cable terminated with male SMA connector	0.5 metres cable terminated with N-Type female connector
Mounting	Stainless steel bracket suit up to 60mm pole (included)	
Wind Survival *km/h*	160	
Temperature Range (Operating)	-20° C to +70° C	
Shock	40G at 10 msec	
Thermal Shock	-20° C to +70° C: 10 Cycles	
IP Rating	IP65 (NEMA 4X)	

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