

Automatic Sector Synthesis System for Wireless Base Station
Antennas based on traffic load

by

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ABSTRACT

Considering mobile wireless networks in Zimbabwe, most base station wireless antennas are positioned in a three sector sequence, which is always symmetric and rigid. NetOne Zimbabwe always maintains this setup while Econet takes a step further by conducting RF optimization and re-arrange the azimuth, the engineers and riggers travel to the site to make alterations and it becomes an extra unexpected expense to the company. This calls for the need to come up with an automatic system that can perform sector synthesis and re-arrange the antennas to the best azimuth position.

DECLARATION

I, **Chiedza Constance Makatya** hereby declare that I am the sole author of this dissertation entitled “Automatic sector synthesis system for wireless base station antennas”. I authorize Midlands State University to this dissertation only for purposes of scholarly research.

Signature..... Date.....

APPROVAL

This dissertation entitled “Automatic sector synthesis system for wireless base station antennas based on traffic load” by **Chiedza Constance Makatya** meets the regulations governing the award of the degree of *Bsc Telecommunications Honours* of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor.....Date.....

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ABBREVIATIONS

RF	Radio Frequency
APM30	Amplified Power Module version 30
BTS	Base Station
ACDB	Alternating Current Distribution Board
BBU	Base Band Unit
TRX	Channels
BSC	Base Station Controller
RNC	Radio Network Controller
EPC	Evolved Packet Controller
LMT	Local Maintenance Unit
RRU	Remote Radio Unit
GGSN	Gateway GPRS Support Node
SGSN	Serving GPRS Support Node

CHAPTER ONE

INTRODUCTION

This project focuses on developing self-orientating wireless smart base station antennas based on traffic density, so as to provide the best network antenna solutions and strengthen the network performance.

1.1 Background

In view of explosive growth in the number of digital cellular subscribers, service providers are becoming increasingly concerned with the limited capacities of their existing networks. [1]. Having had worked in the GSM Wireless department during work related learning year at Huawei Technologies Zimbabwe and participating in one of the biggest projects in Zimbabwe Telecommunications, the NetOne National MBB project in which a large number of base stations were installed nationally, the student observed that most of the areas that were being installed had a coverage area that was not evenly distributed, even though the antennas were being installed in uniform sectors which were 120 degrees apart. With this type of network planning it means that if one sector is densely populated maybe facing a high density residential area and the other spatially distributed (see figure 1.1). From the picture the antenna on the 120 degrees sector has a greater chance of experiencing congestion since its serving a densely populated area and sector 0 degrees can be configured to back up sector 120 degrees. Some wireless antennas on the base station would not being fully utilized while some are operating at full capacity thus causing cell overloading problems.

The common problem of cell overloading include paging constrains, call congestion and call drops [2]. These problems will cause serious network degradation leading to loss of revenue for the network provider. If the network provider realizes this problem and they wish to correct the orientation to favor the more populated area, the engineers and the rigging team have to travel a long distance to the base station site, which can be expensive and time consuming. Thus an automated system which can perform remote azimuth optimization is needed to overcome these challenges.

The photo for site environment

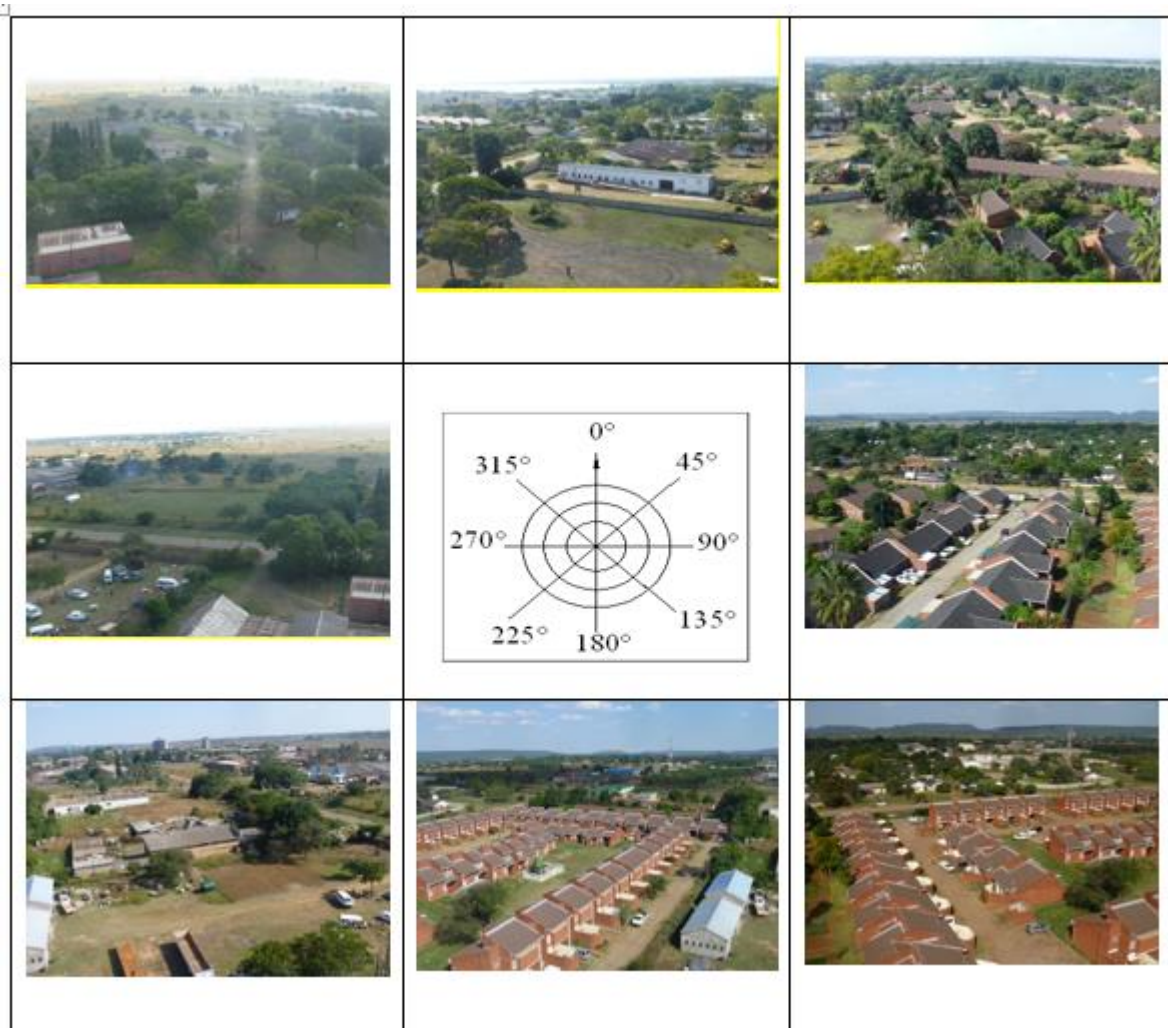


Figure 1.1: Geographical survey picture

From Figure 1.1 the antenna on the 120 degrees sector has a greater chance of experiencing congestion since it is serving a densely populated area and the sector facing 0 degrees can be configured to back up sector facing 120 degrees.

1.2 Overview of Automatic Sector Synthesis system for Wireless Base station antennas based on traffic density

The research project is going to demonstrate the sequence of orientation of the wireless antennas on a base station as the traffic load varies in each and every sector. The proposed system will use a smart antenna base station model which implements the use of a microcontroller, potentiometers and servo motors. The antenna system rotates the antenna panels towards the busy sector to fight congestion and overloading thus improving mobile network delivery. Variations of resistances in the potentiometer of a sector will be represent traffic density. Servo motors will be used to control the rotation of the panel according to the degrees required.

1.3 Aim of study

To design a smart base station antenna system that holds the capability of automatically changing the orientation of the least active antenna to assist the antenna in the sector that is overloaded. In this project a demo prototype is going to be used to illustrate the project's idea.

1.4 Objectives of study

- To study the use of sector synthesis techniques as a way of RF network optimization.
- To assess the possibility of using smart antennas which have the capabilities of changing their azimuth to adapt to the current environment state.
- To study the relationship between antenna radiation patterns and network congestion.
- To design a demo prototype of a base station, where the potentiometer variations represents traffic density of an area.
- To rotate the dummy antenna panel to the desired position depending on the thresholds set.

1.5 Justification

A good network plan should address the coverage and capacity requirement of an area, but also be sufficiently flexible to allow network expansion without major change of the existing sites. [3]. Improper rationing of wireless antenna panels to the network users density on the three antenna system can be a major contribution to coverage and capacity problems. In cellular systems, the geographical area covered by a base station and the capacity per given time is not constant. [4].

This project will focus on the importance of implementing self-orienting smart antenna systems based on sector synthesis techniques in this country. This system will increase capacity and reduce the effects of a congested network. It focuses on delivering the best network power to the end users at the same time gives the network provider the maximum revenue available at that specific time as it tries to capture every user trying to connect on his network by rotating the alternative smart antenna's lobes towards the antenna with the sector holding the highest network users. The users who were failing to connect to the network will be connected through the antenna that would have rotated.

The system is automatic and therefore will save the operator expenses of travelling to the base station to make installation alterations to favour the region with more subscribers, and also network demand changes throughout the day so it will be cumbersome or impossible to physically change the azimuth here and then.

1.6 Literature Review

RF optimization is always an ongoing process in mobile networks as it always seeks to locate loopholes in the network. It is done to identify weaknesses of the network so that network planning engineers can come up with the appropriate solutions and provide the best network.

Azimuth optimization is a common RF optimizing scheme, where antennas are set at specific angles to each other. In Zimbabwe most mobile network operators always fix the antenna azimuth at specific positions which remain rigid, except for Econet which implements sector synthesis technique manually. The riggers are the ones who change the azimuth manually.

In this project an automated system that performs RF optimization and acts upon the results is proposed and no work has been done so far in developing an automated sector synthesis system.

1.7 Dissertation Layout

Chapter 2 is the Theoretical aspects. In this chapter a review of the current wireless antenna optimization systems and all the aspects that make up the dissertation topic will be outlined.

Chapter 3 outlines the research methods used and all the steps that were taken to complete this dissertation.

Chapter 4 is the Results and Analysis section. The results obtained from the designed prototype are analyzed and compared to the expected results and a conclusion will be made based on the relationship of the two.

Chapter 5 is the conclusion and recommendations chapter.

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- [2] F. Ricciato, D. Widhalm, M. Craglia, F. Pantisano, "Estimating Population Density Distribution from Mobile Phone Data," Joint Research Centre, Ispra, 2015.
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CHAPTER TWO

THEORATICAL ASPECTS

2.1 Introduction

In this chapter, the researcher gives the necessary theoretical background in line with wireless network overview, sector synthesis and load balancing. The designer also takes a step by step analysis of the components used in developing the demo prototype of the base station system. Diagrams, tables and mathematical equation have been included to clarify various important aspects. Graphs have been simulated using Matlab software.

2.2 Overview of Mobile wireless network

The first mobile telephone service was introduced in 1946 by At&T. Within a year, mobile telephone service was offered in more than twenty five American cities. They were based on Frequency Modulation (FM) transmission and they used a single powerful omnidirectional transmitter to provide coverage of radius of sixty kilometres or more from the base station.

The few available channels were spread over a large area which means that subscribers had to share the few channels creating spectrum congestion.

Around the 1970s, Bell Labs introduced the first cellular telephone system to reduce the problem of spectrum congestion. The term cellular refers to dividing the service area into many small regions or cells each served by a low power transmitter with automatic call handoff from one cell to another. In the late 1970s, the first generation cellular system was standardized in the United States, called Advanced Mobile Phone System 1G (AMPS) [1] . It used the frequency band around 850MHz and had 666 or 832 channels in a cell. The data channels were analog and used FM, while the control channels were digital and used Frequency Shift Keying (FSK) modulation.

In 1990, the first phase of Global System for Mobile communication 2G (GSM) which is based on Time Division Multiple Access (TDMA) was published. GSM system uses the 900MHz frequency band. Each RF channel occupies 200KHz band and has eight speech channels with 270 bps bit rate. The second phase General Packet Radio Access 2.5G (GPRS) based on the GSM system was introduced and provided low-rate packet-switched data service of up to 64

Kbps through Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN).

However due to the increase in mobile phone usage for both voice and data, a 3G technology was introduced which is the Universal Mobile Telecommunications System (UMTS) with WCDMA. UMTS offer higher data rates upto 2Mbps and higher spectrum efficiency [2].

Due to the tremendous growth in the demand of bandwidth a more advanced technology Long Term evolution (LTE) was introduced. LTE is a fourth generation (4G) technology which supports IP (Internet Protocol) based packet switching communication system with OFDM multi-carrier transmission and other frequency domain schemes which offer high data transfer rates. It uses Orthogonal Frequency Division Multiple Access (OFDM) in the downlink and Single Carrier Frequency Division Multiple Access in the uplink.

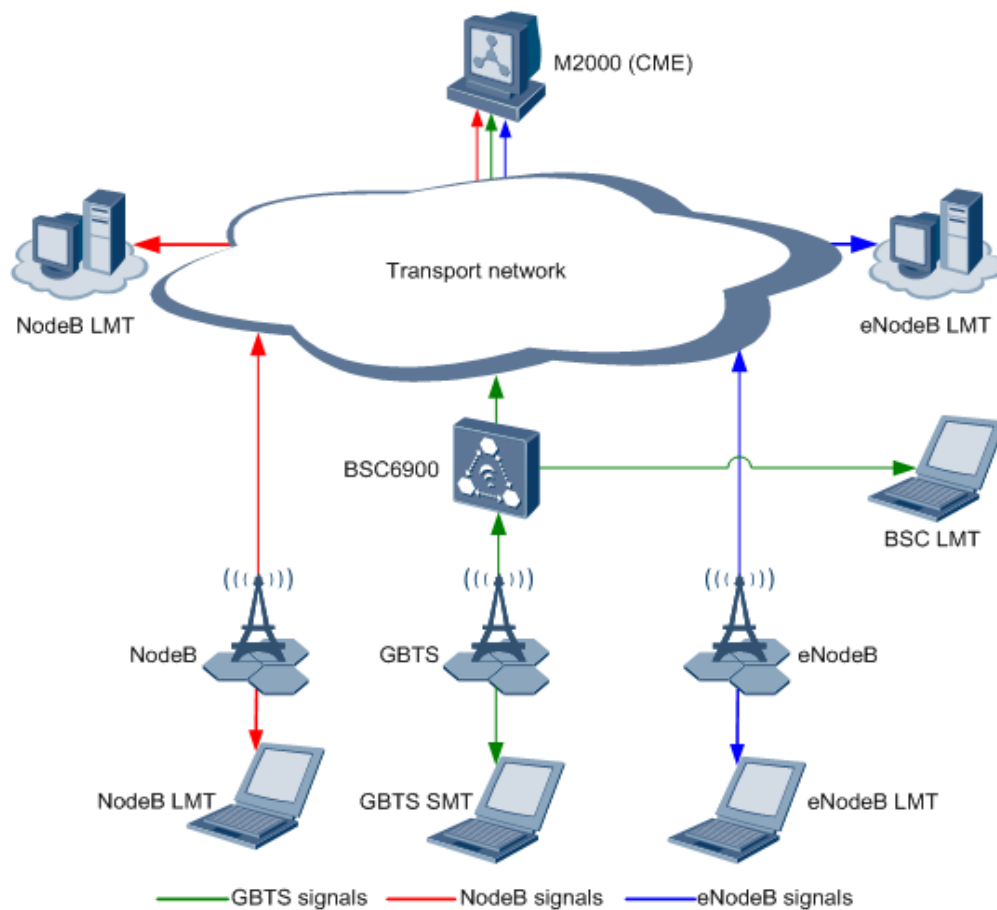


Figure 2.1: GSM, UMTS and LTE network system [3]

Figure 2.1 show the combined networks architecture, showing the points on which network operators can login the network elements to collect data, operate and maintain the network. They login through the LMT, SMT and CME access points.

2.3 Antenna theory

2.3.1 Antenna definition

An antenna is a conductor that is able to transmit or receive signals such as microwave, radio and satellite signals. It transmits by converting Radio Frequency signals to Alternating Current (AC) signals and receives by reconvertng the AC signals to Radio Frequency signals [4]. Figure 2.2 below shows a simple wireless antenna system meant for either transmission or reception.

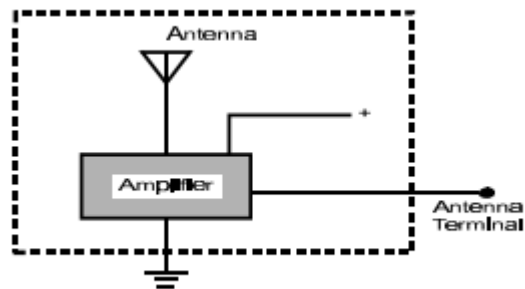


Figure 2.2: Antenna system

There are different types of antennas depending on their applications and requirements of the network under consideration. These types include wire antennas, Log-Periodic antennas, Aperture antennas, Travelling wave antennas, Reflector antennas and Microstrip antennas.

2.3.2 Wave propagation

Antennas propagate electromagnetic waves. Electromagnetic waves are produced by an oscillating circuit connected to an antenna as shown in Figure 2.3. The oscillating charges in the antenna set up electric and magnetic fields.

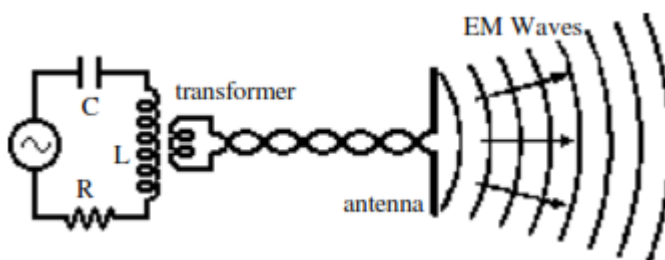


Figure 2.3: Wave generation

The waves are initially produced by the charges on the antenna. The charges produce an E-field and the motion of the charges (current) produces a B-field. Later when the current switches directions, fields also switch directions near the antenna. However, the changing fields away from the antenna induce more fields as described in Figure 2.4. The propagation of waves

are best described using Maxwell's Laws of Electricity and Magnetism. The changing magnetic field producing an electric field and the changing electric field produces a magnetic field. This is the nature of the EM waves.

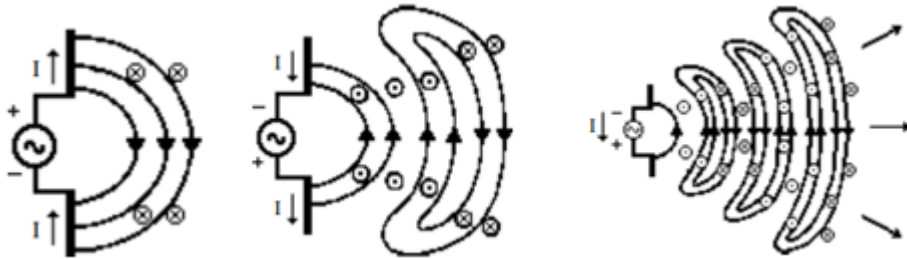


Figure 2.4: Wave propagation

EM waves can be detected at the receiving end by the receiver antenna (Figure 2.5). The charges in the antenna are forced to oscillate by the EM waves and the resulting voltages are processed further.

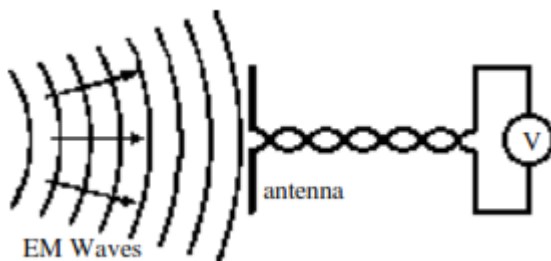


Figure 2.5: Wave reception

The four Maxwell's equations form the foundation of propagation of electromagnetic waves. It describes the relationship between charges, current, electric and magnetic fields as the waves travel in space. The equations are stated in Table 2.1:

Table 2.1: Maxwell's equations and their interpretation [5]

Law	Equation	Physical Interpretation
Gauss's law for \vec{E}	$\oiint_S \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$	Electric flux through a closed surface is proportional to the charged enclosed
Faraday's law	$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$	Changing magnetic flux produces an electric field
Gauss's law for \vec{B}	$\oiint_S \vec{B} \cdot d\vec{A} = 0$	The total magnetic flux through a closed surface is zero
Ampere – Maxwell law	$\oint \vec{B} \cdot d\vec{s} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$	Electric current and changing electric flux produces a magnetic field

2.3.3 Antenna categories

Antennas can be clustered into three categories mainly omni-directional antennas, semi-directional antennas and directional antennas.

Omni-directional antenna

These antennas radiates or intercepts RF electromagnetic signals in all horizontal directions equally. They are used in consumer RF wireless devices including cellular sets and wireless routers. They require very high transmit power since the radiation pattern is distributed around the antenna and they provide signal over a short distance.

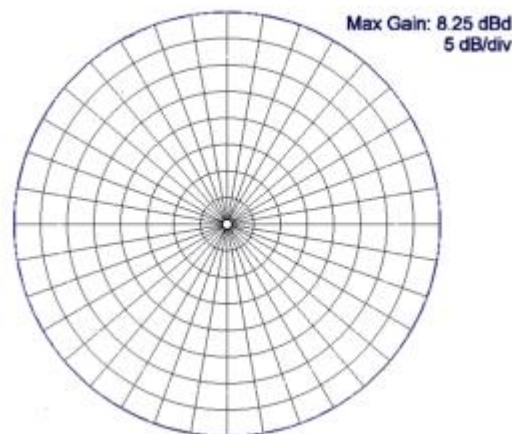


Figure 2.6: Omni-directional radiation pattern

Semi-directional antennas

These antennas propagate the signal in a constricted fashion which is defined by a specific angle. An example is a Yagi antenna, which uses several elements to form a semi-directional array. A single driven element propagates RF energy, the elements placed immediately in front of and behind the driven element re-radiate RF energy in phase and out of phase, enhancing and retarding the signal, respectively.

Radiation diagrams with relative field strength

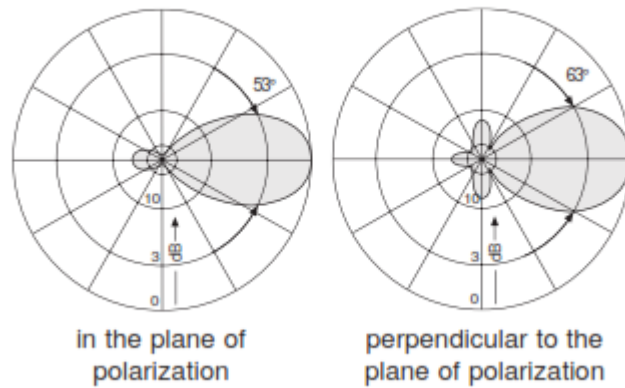


Figure 2.7: Yagi antenna radiation pattern

Directional antennas

The antennas provide a narrow beam that allows highly directional propagation. Directional antennas are mainly used for point to point links and base station wireless systems for example microwave links and sector antennas respectively [6]. Since the radiation power is focused in a particular direction it travels a longer distance thus providing a larger coverage area. These antennas are used in mobile network for wireless mobile communication between the base station and the mobile equipment. The radiation pattern is shown in Figure 2.8.

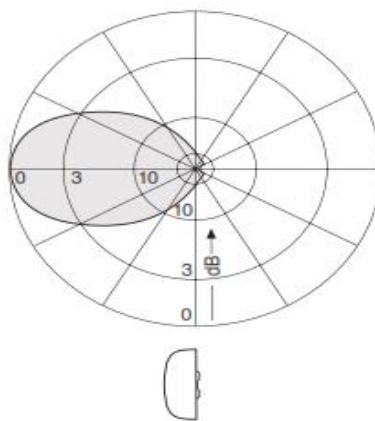


Figure 2.8: Directional antenna radiation pattern

2.3.4 Antenna parameters

Radiation pattern

Radiation pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The pattern comprises of

the main lobe, minor lobes, side lobes and back lobes. Figures 2.6, 2.7 and 2.8 show the radiation patterns for different types of antennas.

Beamwidth

The beamwidth of an antenna is often used as a trade-off between it and the side lobe level, that is, as the beamwidth decreases, the side lobe increases and vice versa. The beamwidth of the antenna is used to label the resolution capabilities of the antenna to distinguish between two adjacent radiating sources or radar targets.

Directivity

It is defined as the ratio of the radiation strength in a given direction from the antenna to the radiation strength averaged over all directions.

$$D = D(\theta, \varphi) = \frac{U(\theta, \varphi)}{U_0} = \frac{4\pi U(\theta, \varphi)}{P_{rad}} \dots\dots\dots (2.1)$$

$$D_{max} = D_0 = \frac{U}{U_0} = \frac{U_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}} \dots\dots\dots (2.2)$$

Where:

- D = Directivity
- D_0 = Maximum directivity
- $U = U(\theta, \varphi)$ = Radiation intensity
- U_{max} = Maximum radiation intensity
- U_0 = Radiation intensity of isotropic source
- P_{rad} = Total radiated power (W)

Antenna Gain

The gain, G of an antenna is the ratio of the radiation power in a specific direction and the radiation power that would be obtained if the power fed to the antenna were radiated in an isotropic way.

$$Gain = 4\pi \frac{\text{radiation intensity}}{\text{total input accepted power}} = 4\pi \frac{U(\theta, \varphi)}{P_{in}}. \text{ (dimensionless).} \dots\dots\dots(2.3)$$

Bandwidth

The ability of an antenna to operate over a wide frequency band. It is the range on which the power gain is maintained to within 3dB of its maximum value.

Effective Aperture

It is the ratio of the available power at the terminals of the antenna to the power flux density of a plane wave incident on the antenna which is matched to the antenna.

$$Ae = \frac{P_r}{S} \dots\dots\dots(2.4)$$

Where:

Ae = Effective Aperture

P_r = Receiver input impedance

S = Receive wave power density

Near Field regions

The near field region is the area close to the antenna. There are two regions in this area which are the reactive region and the radiating region. The reactive near-field region immediately surrounds the antenna where the reactive field predominates and it is non-radiating. The radiating near-field region is the region between the reactive near-field region and the far-field region where radiation fields predominates. It is also called the Fresnel Region.

Far Field regions

It is also called the Fraunhofer region. This is the region where the angular field distribution is essentially independent of the distance from the antenna. It is the area furthest from the antenna.

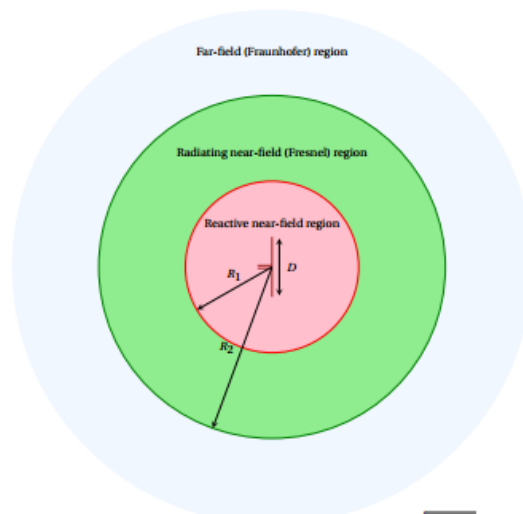


Figure 2.9: Near and far field regions

2.3.5 Wireless Antenna connection on base station

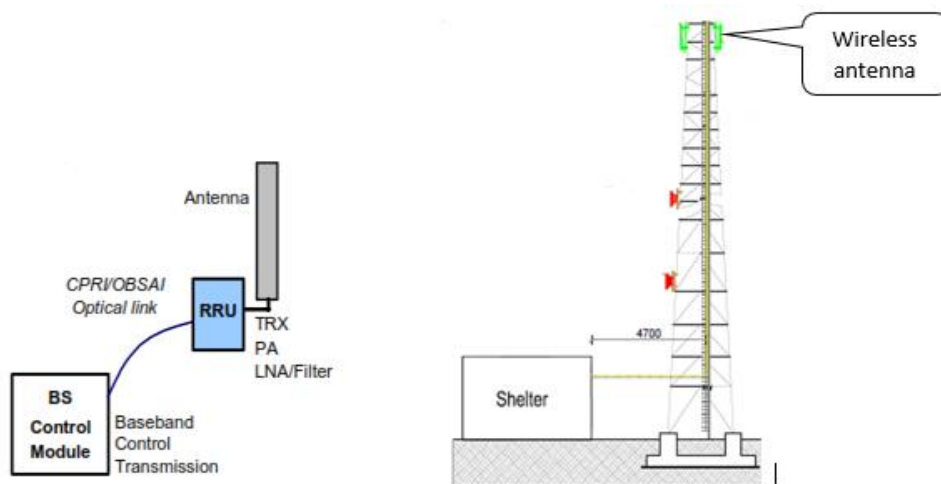


Figure 2.10: Base station [7]

The base station consist of a tower and a shelter. The tower holds the wireless and microwave antennas at a specified height. The wireless antenna is connected to the Baseband Unit (BBU) through the Remote Radio Unit (RRU), using CPRI optical links. The BBU is housed in a cabinet inside the shelter.

2.4 Traffic analysis

Traffic in telecommunications is defined as either the amount of data or the number of messages over a circuit during a specific period of time. Traffic also explains the relationship

between call attempts and the speed with which the calls are completed. Traffic analysis enables one to determine the amount of bandwidth needed in the circuits for data and for voice calls.

Traffic is measured in loads. Traffic load is the ratio of call arrivals in a given period of time to the average amount of time taken to service each call during that period. The measurements units are Average Hold Time (AHT).

$$AHT = \frac{\text{call seconds}}{\text{number of calls}} \dots\dots\dots (2.5)$$

The two mainly used units for traffic load measurements nowadays are the erlangs and centum call seconds (CCS). The unit to use depends highly on the equipment.

One erlang is 3600 seconds of calls on the same circuit, or enough traffic load to keep one circuit busy for 1 hour.

$$Erlangs = \frac{\text{number of calls} * AHT}{3600} \dots\dots\dots (2.6)$$

One CCS is 100 seconds of calls on the same circuit. Voice switches are the ones which measure the amount of traffic in CCS.

$$CCS = \frac{\text{number of calls} * AHT}{100} \dots\dots\dots (2.7)$$

2.4.1 Traffic engineering

These use mathematical formulas and software to make configuration decisions about the network serves and the Grade of Service needed to serve a certain capacity of subscribers. This technique uses the Erlang B formula which is used when a blocked call is really blocked—for example, when somebody calls your phone number and gets a busy signal or tries to access a tie trunk and finds it in use. Erlang B tables were developed to make it easier for engineers to determine the number of channels needed for their traffic [8].

Grade of Service (GoS): The probability that all servers will be busy when a call attempt is made. P.02 means that there is a 2% probability of getting a busy signal (being “blocked”) when you have a given amount of traffic and a given number of trunks. Blocking probability refers to the probability that a new user will find all channels busy and hence be denied service. In CDMA systems, this corresponds to the case when the overall interference in the system is above a certain threshold. A GoS of 0,01% means that the callers will

never get a busy tone, while GoS of 10% degrades the network's quality. The most used GoS probability is 2% [8]. GoS probability is calculated as follows:

$$(\text{GoS}) P = (A^x / N!) / (\sum_{x=0}^N A^x / x!) \dots\dots\dots(2.8)$$

N = number of channels

A = traffic load (Erlangs)

Table 2.2: An extract of Erlang B table

No. of Trunks (N)	Traffic (A) in erlangs for P =															
	0.1%	0.2%	0.5%	1%	1.2%	1.3%	1.5%	2%	3%	5%	7%	10%	15%	20%	30%	40%
1	0.001	0.002	0.005	0.010	0.012	0.013	0.02	0.020	0.031	0.053	0.075	0.111	0.176	0.250	0.429	0.667
2	0.046	0.065	0.105	0.153	0.168	0.176	0.19	0.223	0.282	0.381	0.470	0.595	0.796	1.00	1.45	2.00
3	0.194	0.249	0.349	0.455	0.489	0.505	0.53	0.602	0.715	0.899	1.06	1.27	1.60	1.93	2.63	3.48
4	0.439	0.535	0.701	0.869	0.922	0.946	0.99	1.09	1.26	1.52	1.75	2.05	2.50	2.95	3.89	5.02
5	0.762	0.900	1.13	1.36	1.43	1.46	1.52	1.66	1.88	2.22	2.50	2.88	3.45	4.01	5.19	6.60
6	1.15	1.33	1.62	1.91	2.00	2.04	2.11	2.28	2.54	2.96	3.30	3.76	4.44	5.11	6.51	8.19
7	1.58	1.80	2.16	2.50	2.60	2.65	2.73	2.94	3.25	3.74	4.14	4.67	5.46	6.23	7.86	9.80
8	2.05	2.31	2.73	3.13	3.25	3.30	3.40	3.63	3.99	4.54	5.00	5.60	6.50	7.37	9.21	11.4
9	2.56	2.85	3.33	3.78	3.92	3.98	4.08	4.34	4.75	5.37	5.88	6.55	7.55	8.52	10.6	13.0
10	3.09	3.43	3.96	4.46	4.61	4.68	4.80	5.08	5.53	6.22	6.78	7.51	8.62	9.68	12.0	14.7
11	3.65	4.02	4.61	5.16	5.32	5.40	5.53	5.84	6.33	7.08	7.69	8.49	9.69	10.9	13.3	16.3
12	4.23	4.64	5.28	5.88	6.05	6.14	6.27	6.61	7.14	7.95	8.61	9.47	10.8	12.0	14.7	18.0
13	4.83	5.27	5.96	6.61	6.80	6.89	7.03	7.40	7.97	8.83	9.54	10.5	11.9	13.2	16.1	19.6
14	5.45	5.92	6.66	7.35	7.56	7.65	7.81	8.20	8.80	9.73	10.5	11.5	13.0	14.4	17.5	21.2
15	6.08	6.58	7.38	8.11	8.33	8.43	8.59	9.01	9.65	10.6	11.4	12.5	14.1	15.6	18.9	22.9
16	6.72	7.26	8.10	8.88	9.11	9.21	9.39	9.83	10.5	11.5	12.4	13.5	15.2	16.8	20.3	24.5
17	7.38	7.95	8.83	9.65	9.89	10.0	10.19	10.7	11.4	12.5	13.4	14.5	16.3	18.0	21.7	26.2
18	8.05	8.64	9.58	10.4	10.7	10.8	11.00	11.5	12.2	13.4	14.3	15.5	17.4	19.2	23.1	27.8
19	8.72	9.35	10.3	11.2	11.5	11.6	11.82	12.3	13.1	14.3	15.3	16.6	18.5	20.4	24.5	29.5
20	9.41	10.1	11.1	12.0	12.3	12.4	12.65	13.2	14.0	15.2	16.3	17.6	19.6	21.6	25.9	31.2

The current maximum antenna configuration is S4/4/4 thus the number of channels is 64 and using a 2% GoS the channels will serve an average of 53.4 erlangs, that is, 1068 subscribers per hour.

2.4.2 Traffic load measurements

Traffic load measurements are used to analyze network performance in terms of capacity versus available resources. Traffic theory enables network designers to make assumptions about their

networks based on past experience. Although the total call seconds in an hour divided by 3600 seconds determines the traffic in erlangs, one can also use averages of various time periods. These averages allow more sample periods to be used and determine the proper traffic load. Thus traffic load per given hour during the day can be determined and the busy hours traffic can be determined enabling temporary optimization during that time. Below is an example of a daily traffic load measurement sample showing the hour of the day and the traffic load measurement of S1/1/1 configuration. Table 2.2 displays the traffic load in erlangs and Figure 2.11 shows the graphical results.

Table 2.3: Daily Peak Traffic load measurement

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Total load
9.00am	12.7	11.5	10.8	11.0	8.6	54.6
10.00am	12.6	11.8	12.5	12.2	11.5	60.6
11.00am	11.1	11.3	11.6	12.0	12.3	58.3
12.00am	9.2	8.4	8.9	9.3	9.4	45.2
1.00pm	10.1	10.3	10.2	10.6	11.0	51.0
2.00pm	12.4	12.2	11.7	11.9	11.6	59.2
3.00pm	9.8	11.2	12.6	10.5	9.8	55.7
4.00pm	10.1	11.1	10.8	10.5	10.2	52.7

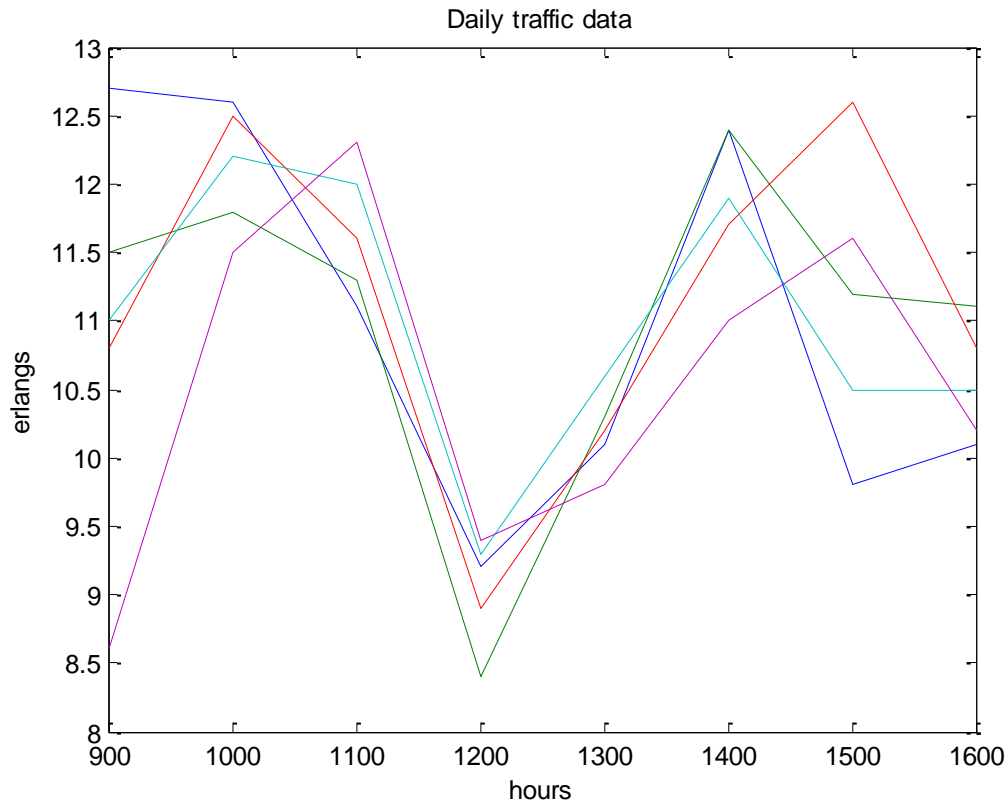


Figure 2.11: Traffic profile

From the graph, the 1000hrs period has the highest traffic load followed by the 1400hrs period, and during these periods the network is likely to suffer from congestion depending on the available resources of the network.

Table 2.4: Traffic measurement

Cell name	DHO001A	DHO001B	DHO001C
Site Name	Kopje_ HRE	Kopje_ HRE	Kopje_ HRE
No. of TCHs	44	44	44
No. of SDCCHs	23	23	23
TCH Traffic (Erlangs)	30.21	0,79	16.01
Total calls (TCALLS)	1059	78	574

The table above shows the results of an ongoing RF optimization procedure for a base station at Kopje in Harare. The results are for a three sectored base station, having 67 channels per sector, of which 44 are dedicated to voice calls (TCH), and 23 are dedicated to data (SDCCH). The voice traffic load for each sector was recorded, and it shows that the first sector is suffering from congestion while sector 2 is almost idle. The users connected to the first sector will not get the best of the network because of the congestion problem.

2.5 Congestion in cellular networks

Network congestion is defined as the situation in which an increase in voice and data transmissions results in a reduction in throughput. When a network is congested, the more data one tries to send, the less data is actually successfully sent and call connection can be difficult or impossible, the available channels would be fully occupied.

As throughput increases on a node, latency increases due to the growing queue delay as shown in Figure 2.15. At first, the increase in latency is rather marginal. However, as the throughput approaches the maximum capacity, latency begins to increase exponentially as it reaches a final tipping point where the element experiences congestive collapse. This interprets that towards the maximum throughput data packets will take longer to reach the final destination causing poor network performance.

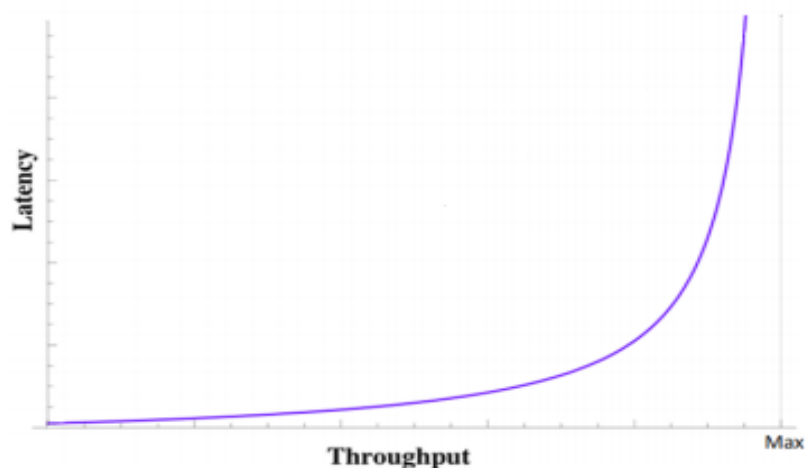


Figure 2.12: Latency versus Throughput.

Congestion can also cause mobile station paging problems resulting in terminated calls and for established calls the signal-to-noise ratio will be too low resulting in poor channel connection.

Network congestion can also affect the radiation pattern of the radiating antennas causing them to shrink in size thus reducing the network coverage [9]. The users at the borders of the cells will no longer be able to connect to the network, this proves that the coverage has moved inwards resulting in reduced coverage area.

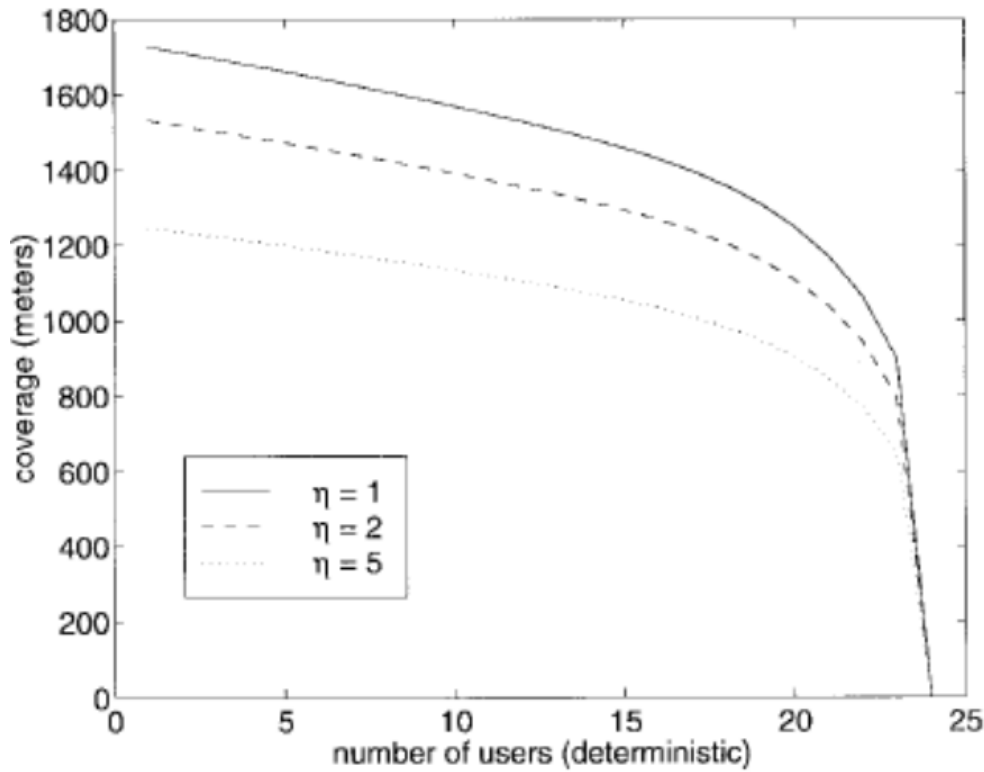


Figure 2.13: Capacity versus coverage graph. [10]

From Figure 2.13, it shows that the increase in the number of users reduces the coverage area thus reducing the radiation pattern of the antennas. Using the graph of $n=1$, when there are 5 users, the coverage area is around 1650m and when there are 20 users the coverage area reduces to 1200m.

Cell congestion is a serious network problem and its impact cause severe network degradation as discussed above. These problems should be addressed so as to optimize the network, improve customer satisfaction, fight industrial competition and increase revenue.

2.6 Sector synthesis techniques

There are so many ways of optimizing the network fighting congestion, but this project is mainly focusing on developing an automated system for antennas which implements sector synthesis technique.

Sector Synthesis is an angle diversity scheme which uses cell site sectorization for increased CDMA capacity and improved network performance. It provides CDMA service providers with flexible tuning options for controlling and managing interference, creating dominant servers, managing handoff activity, and dealing effectively with non-uniform distributions [14]. Working within a three-sector configuration, operators can adjust sector azimuth pointing angles in 30-degree increments, selected from sector beam widths of 60, 90, 120, 180 and 240 degrees, and also change gain settings to expand or contract the radiation pattern in highly localized areas. After network optimization is done engineers record traffic distribution around a base station, and basing on that information the engineers and riggers travel to the base station site to set the azimuth angles that best suit the traffic measurement distributions.

The figure below shows the results of implementing sector synthesis techniques on a wireless network. Figure 2.14a shows a uniform distribution of antennas but the capacity of users is not evenly distributed, causing strain in sector labelled alpha. Figure 2.14b shows the results of implementing the sector synthesis, the antennas are not evenly distributed but the users are by some degree distributed, thus reducing network congestion in sector alpha

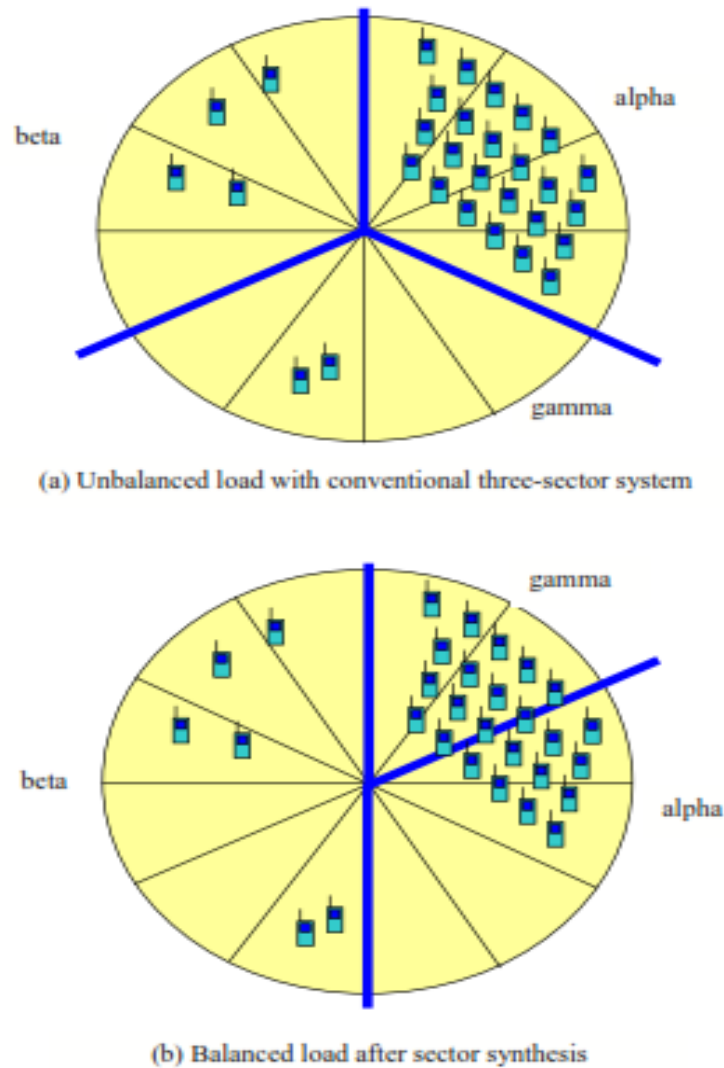


Figure 2.14: Sector Synthesis technique.

2.6.1 Sector synthesis techniques in Zimbabwe

The mobile network technology in Zimbabwe is quite backward and rigid as compared to the rest of the world. Most of the telecommunications companies in this country do not implement this technique. NetOne and Telecel always leave their antenna at 0, 120 and 240 degrees, even if their antennas need azimuth optimization, they are only concerned with providing equal coverage from the antenna position, they do not mind about providing equal capacity distribution from the antennas. Econet Zimbabwe works quite differently, after installing the antennas at 0, 120 and 240 degrees, the engineers perform an on-going RF optimization and if the azimuth need to be altered, they travel to the base station to perform sector synthesis because they are concerned with harvesting more capacity than just coverage.

2.7 Related ways of performing optimization on a congested network.

2.7.1 Cell splitting

Cell splitting is a built-in feature in the cellular systems. It is done by adding new BTSs thus reducing size of a cell. Yielding more cells provides for an increasing amount of channel reuse and, hence, increasing subscriber serving capacity. Urban centres can be split into as many areas as necessary to provide acceptable service levels in heavy-traffic regions, while larger, cells can be used to cover remote rural regions.

However cell splitting will reduce the radii of the cell resulting in more cell handovers that means the rate of power drainage from the mobile station will be high. In addition, installation of more BTSs in a small area is costly.

2.7.2 Cell sectorization

In this scheme, each cell is divided into three or six sectors and uses three or six directional antennas at the BTS. Each sector is assigned a set of channels (frequencies) called TRXs. Because of the use of directional antennas, the number of interfering cells is reduced. This increases the channel reuse rate and also increase the system capacity and coverage [11].

2.7.3 Cell breathing

In this technique the size of a cell shrinks as the load increases, and expands as the load decreases. The heavily loaded cells will have to handoff some of its users to the overlapping region [12]. Due to the reduced coverage this technique does not increase system capacity and the user at the cell fringe might encounter some problems in making calls.

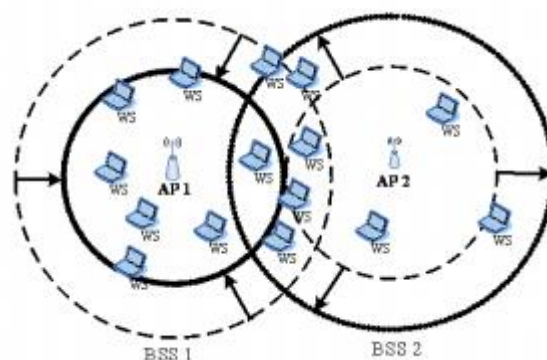


Figure 2.15: Cell breathing technique. [13]

From Figure 2.15, the cell in BSS1 became heavily loaded and shrunk in size then it handed some of its users to BSS2 for load sharing.

2.8 Prototype components description

2.8.1 Arduino processor

It is an open-source physical computing platform based on a simple I/O board and a development environment that apparatuses the Processing/Wiring language and it is composed of two major parts: The Arduino board (hardware) and the Arduino IDE (software) . The program responsible for the control and manipulation of devices connected to the Arduino is written using the IDE [15].

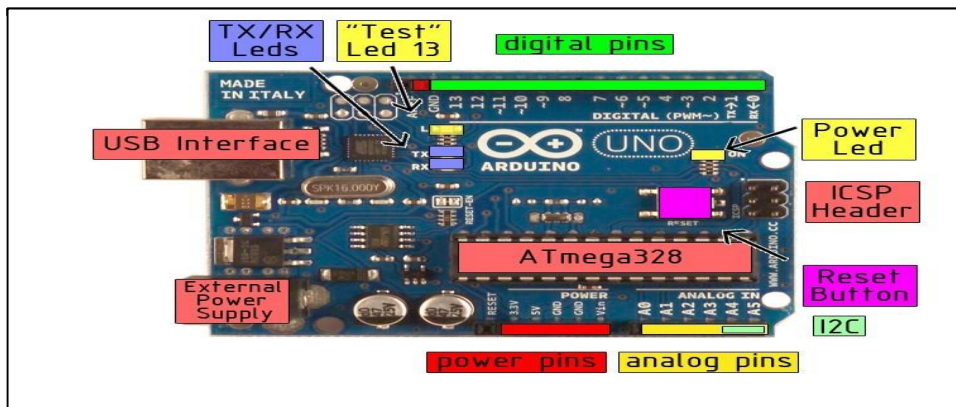


Fig 2.16: Arduino Uno Top side.

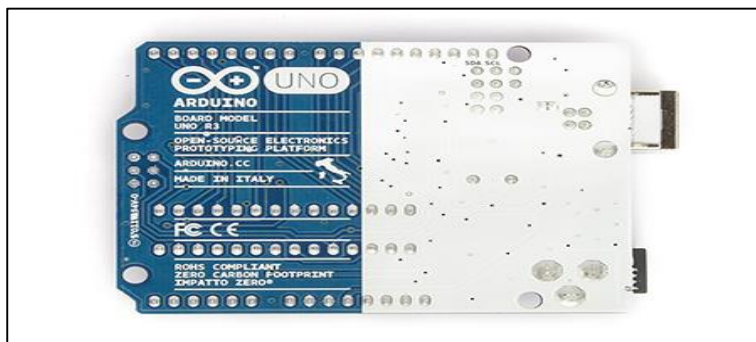


Fig 2.17: Arduino Uno backside.

Key features

Arduino implements the use of the ATmega328 microcontroller. It has 14 digital I/O pins (PWM uses six of the output pins), 6 analog inputs, a reset button, an on-board resonator, and mounting pin headers' holes [16].

2.8.2 ATmega328 Mapping

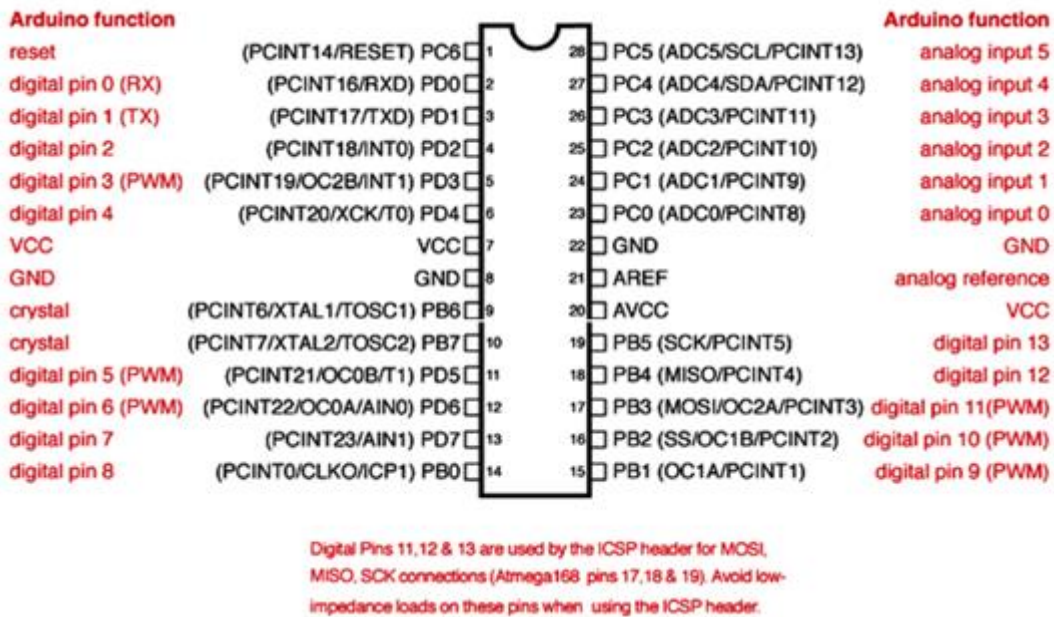


Fig. 2.18: ATmega328 Mapping.

The ATmega238 is the heart of the system, it requires a program for it to perform all the tasks it is required. A code for a certain task is written and debugged and uploaded to the Arduino board through a com port.

The Arduino has 14 digital input/output pins , 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller and it is simply connected to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Table 2.4: Arduino Uno power pin description

Pin	Description
Vin.	The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source).
5v	This pin outputs a regulated 5V from the regulator on the board.
Gnd	These are the ground pins.
I/O ref	This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the I/O REF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V

2.8.3 Servo motor



Figure 2.19: Servo motor

The servo motors are motors that allow for precise control. They consist of a motor coupled to a sensor for position feedback, through a reduction gearbox. As a result, servo motors are used to control position of objects, rotate objects, move legs, arms or hands of robots and move sensors with high precision. The servo motor serves as an actuator in a robotics system. They are small in size. They have built-in circuitry to control their movement therefore they can be connected directly to an Arduino Uno processor.

Operation

The principle of operation is quite simple. The position of the servo motor is set by the length of a pulse. The servo expects to receive a signal pulse roughly every 2.0 milliseconds. If a pulse is high for 1 millisecond, then the servo angle will be zero, there is no rotation. If the pulse is 1.5 milliseconds, then it will be at its centre position, the servo rotates through 90 degrees. If it is 2 milliseconds it will be at 180 degrees. Thus a servo motor can be programmed to rotate to a specific desired position.

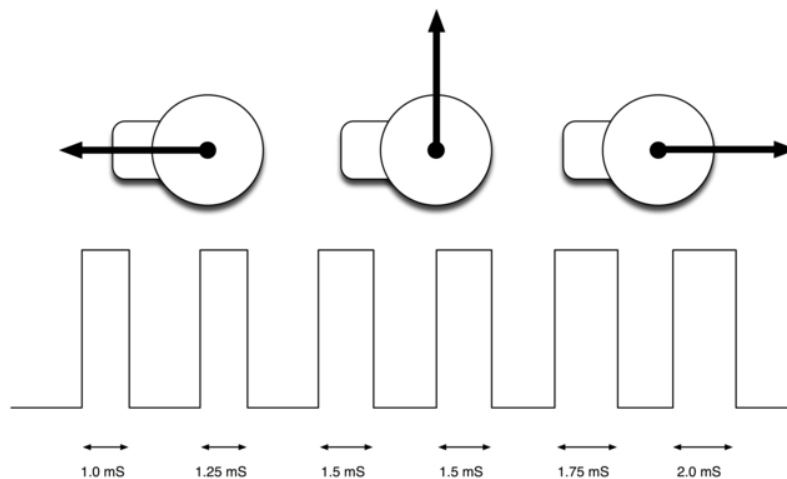


Figure 2.20: Servo motor operation

2.8.4 Potentiometer



Figure 2.21:10K potentiometer

A potentiometer is a simple knob that provides a variable resistance. It does so by adjusting a variable tap (wiper) along a resistance by some mechanical movement.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines the methods and assumptions that the researcher used to carry out the steps of bringing the idea of this dissertation to life, it also explains the design characteristics of all interfaces used, together with the software tangled in carrying out this project. It gives an overview of the system implementation procedure, block diagram, a summary on how the code will be executed and the data searching technique that was implemented.

3.2 Automatic sector synthesis system for wireless base station antennas based on traffic density

Automatic sector synthesis system is an advanced angle diversity technique where the base station system performs analysis on the received traffic data for each sector then it comes up with a suitable antenna azimuth position based on the data. This system is suitable for areas with non-uniform and time varying traffic distribution. With automatic sector synthesis system capabilities, operators can create antenna patterns specifically designed for local traffic patterns and terrain without repeatedly travelling and climbing towers to mount custom antennas. These system also enable maximum revenue each particular time.

3.2.1 Industrial system architecture

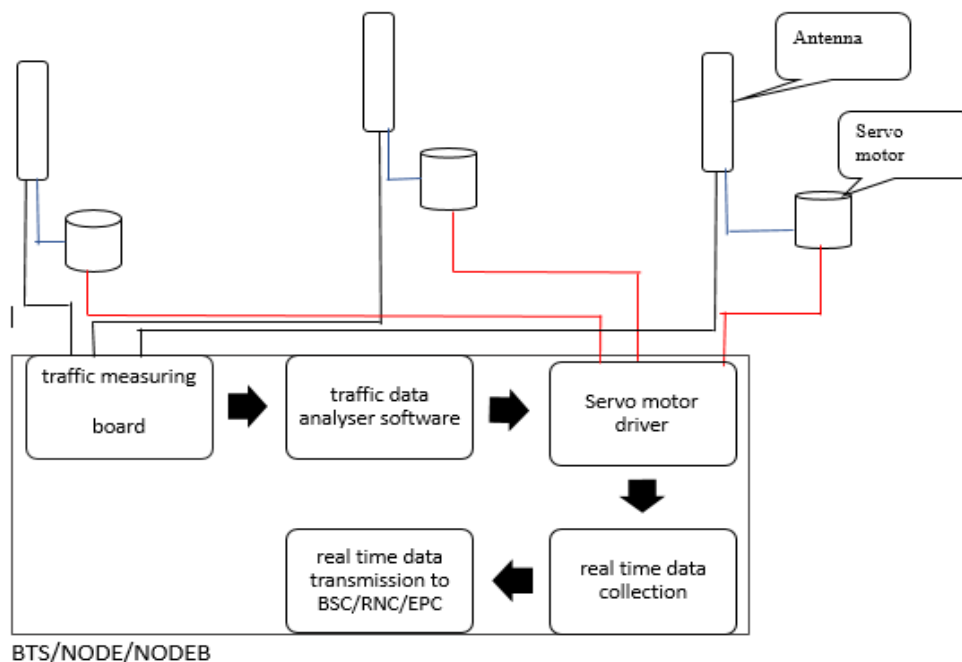


Figure 3.1: Automatic sector synthesis system architecture.

The system comprises of three servo motors connected to the antennas and traffic measuring and analyser equipment housed in the base station cabinet. The traffic measuring board records the traffic carried per sector at any given time. The board measures the traffic for sector 1, sector 2 and sector 3 simultaneously. The information is then analysed by the traffic analyser software to determine the capacity carried by each sector and if a sector is above eighty percent full the configured antenna will rotate to ease the potential congestion, thus load sharing. The servo motor drivers will rotate the antennas as directed by the microprocessor basing on the information obtained from the analyser software. For instance if traffic load on sector 1 is more than an eighty percent full, the antenna in sector 2 will rotate 30 degrees towards sector 1 only if the traffic load on sector 2 is low say less than forty percent. When the traffic load on sector 1 falls below eighty percent the antenna for sector 2 returns to its original position. This sequence applies for the other sectors. If all sectors reach the eighty percent or above, an alarm is sent to the switch room to notify the responsible engineers so as to perform network optimization and consider other ways of expanding the network. For visual data acquisition the real time data is collected and saved in the base station server and also transmitted to the BSC/RNC/EPC gateway switch room. The wireless engineers can login the LMT, SMT or CME access points to manage the operation of the system.

3.3 Base station demo prototype

To illustrate the rotation sequence of the base station antennas, a demo base station prototype is designed, as it is impossible to convince telecommunications companies to alter their antenna azimuth in fear of being sabotaged.

The demo system consist of a dummy base station, three servo motors, three potentiometers and the Arduino Uno microprocessor.

3.3.1 Block Diagram

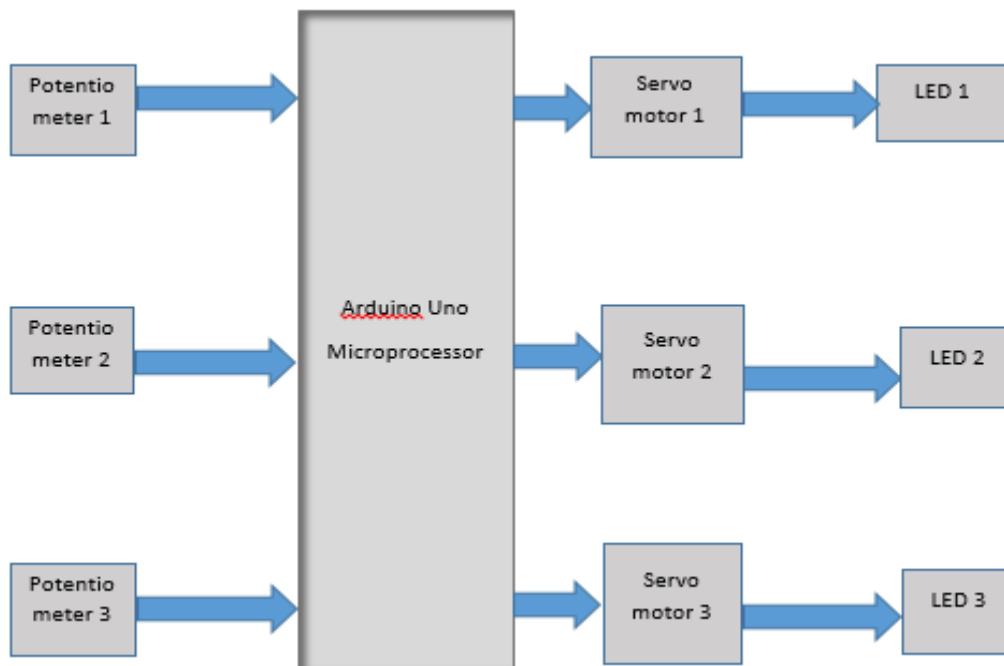


Figure 3.2: System block diagram

The block diagram in Figure 3.2 shows the rotation sequence of the dummy antenna system. When the resistance in the potentiometer reaches 4,4 k ohms the data is manipulated and analysed by the Arduino Uno processor and the corresponding code sequence is executed. (**The wiper of the potentiometer is to be moved from the maximum resistance, therefore the 22K ohms point marks the lowest traffic load and 0k ohms mark the maximum traffic load**). The corresponding servo motor is activated and rotates accordingly. For instance, if Potentiometer 1 reaches 4,4 k ohms the Arduino Uno processor activates Servo motor 2 given that Potentiometer 2 is not also below 13.2 k ohms, otherwise Servo motor 2 will not be activated. If Potentiometer 2 reaches the set value the processor will activate Servo motor 3, only if Potentiometer 3 has not reached the minimum threshold value. The same applies for Servo motor 1, it can only be activated if Potentiometer 3 has reached the threshold value and if Potentiometer 1 is below the minimum threshold value. The servo motors can only rotate to the original positions if the corresponding potentiometers fall below the threshold values. If all values of the three potentiometers reach 4,4 k ohms or above, a visual alarm is activated notifying that all sectors are above the threshold values.

3.3.2 Prototype system architecture

The wipers of Potentiometer 1, 2 and 3 will be connected to A0, A1, and A2 analogue pins of the Arduino Uno board respectively. The pins A0, A1, and A2 will be the variable analogue

input to the ATMEG processor. The output signal to the Servo motor 1, Servo motor 2 and Servo motor 3 are connected through digital pins D7, D8, and D9 respectively. The servo motor corresponding LEDs are connected on digital pins D11, D12 and D13. The power supply to the servo motors and potentiometers is 5 volts. The system architecture is shown below. It was developed using an online circuit simulator (123D circuits). The code for the dummy base station was developed using the Arduino Uno platform. The circuit layout was also developed using 123D circuit online simulator.

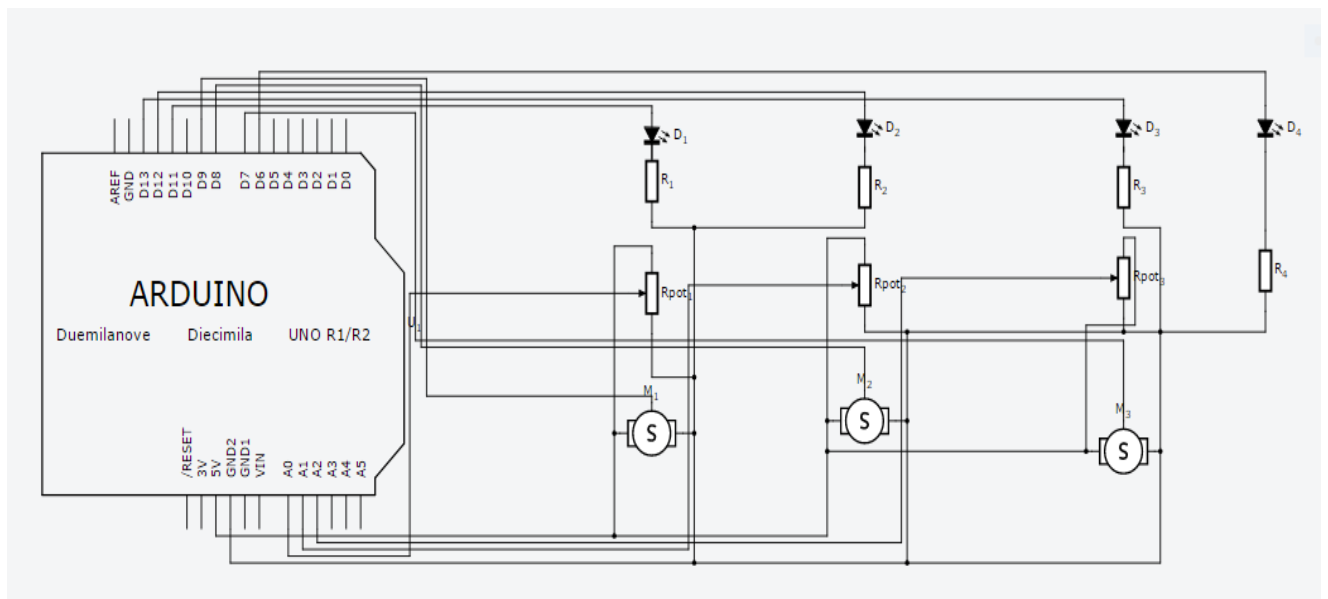


Figure 3.3: Automatic sector synthesis system circuit diagram [1]

The resistance variations in the potentiometer will be matched to real traffic measurements so as to fully mimic the behaviour of the demo prototype to a real antenna system. The sectorized antennae have four main configurations which are S1/1/1, S2/2/2, S3/3/3 and S4/4/4. This means that for the first configuration, there is one TRX in each sector, for the second, there are two TRX in each sector, the third configuration has three channels per sector and the fourth configuration has four channels. The total number of TRX, total channels, Maximum Erlangs, and maximum subscriber per sector are shown in table 3.1. The data was tabulated using the Erlang B table.

Table 3.1: Traffic measurements per sector

Antenna config	TRX (per sector)	Timeslots (per sector)	Traffic load (erlangs)	Blocked calls cleared (P) (%)	Subscribers (per sector)
S1/1/1	1	16	9,83	2	196
S2/2/2	2	32	23,7	2	474
S3/3/3	3	48	38,4	2	768
S4/4/4	4	64	53,4	2	1068

The number of subscribers is calculated by dividing the traffic load by 50mErlangs.

3.4 Questionnaire

The data gathering technique that is to be used is in form of a questionnaire. A questionnaire is a pre-defined set of questions assembled in a pre-determined order, which correspondents are then required to answer, thereby providing the researcher with data that can be analysed and interpreted [2]. An open ended questionnaire will be submitted to the Huawei Wireless engineers to elaborate more on the feasibility of the project. The questionnaire is open ended so that they can give a wide range of responses.

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CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

In this chapter the results that were obtained from the previous chapter setup are analyzed to check the feasibility of the system. The results are presented in the form of tables and graphs.

4.2 Prototype results and analysis

4.2.1 Results

Table 4.1 shows the digital input and digital outputs of the system circuit in Figure 3.4. The system was implemented successfully and the commands were executed repeatedly to verify the results.

NB: The wiper of the potentiometer is to be moved from the maximum resistance, therefore the 22K ohms point marks the lowest traffic load and 0k ohms mark the maximum traffic load.

Table 4.1: System input/output truth table

Pot 1	Pot 2	Pot 3	LED 1	LED 2	LED 3	LED 4	Servo 1	Servo 2	Servo 3
0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	1	0
0	1	0	0	1	0	0	0	0	1
0	0	1	0	0	1	0	1	0	0
1	1	0	1	1	0	0	0	0	1
0	1	1	0	1	1	0	1	0	0
1	0	1	1	0	1	0	0	1	0
1	1	1	1	1	1	1	0	0	0

Since the dummy base station system was used to illustrate the concept of automatic sector synthesis the results obtained from the circuit were merged to real antenna systems. The maximum resistance value was merged to the minimum traffic load, the eighty percent resistance threshold values (max threshold) were merged to the traffic maximum threshold values and also the forty percent resistance threshold values (min threshold) were merged to the traffic minimum threshold value, and the minimum resistance value was merged to the maximum traffic load. The obtained results are shown in the proceeding tables

Table 4.2 Minimum traffic load

Sectors	Theoretical resistance (K Ω)	Actual resistance (K Ω)	Actual S1/1/1 load	Actual S2/2/2 load	Actual S3/3/3 load	Actual S4/4/4 load
Sector 1	22	20,9	0	0	0	0
Sector 2	22	21,5	0	0	0	0
Sector 3	22	20,1	0	0	0	0

Table 4.3: Minimum Threshold traffic load

Sectors	Theoretical resistance (K Ω)	Actual resistance (K Ω)	Actual S1/1/1 load	Actual S2/2/2 load	Actual S3/3/3 load	Actual S4/4/4 load
Sector 1	13,2	12,6	78	189	307	427
Sector 2	13,2	12,9	78	189	307	427
Sector 3	13,2	12,1	78	189	307	427

Table 4.4: Maximum Threshold traffic load

Sectors	Theoretical resistance (K Ω)	Actual resistance (K Ω)	Actual S1/1/1 load	Actual S2/2/2 load	Actual S3/3/3 load	Actual S4/4/4 load
Sector 1	4,40	4,41	154	374	606	843
Sector 2	4,40	4,62	153	372	602	838
Sector 3	4,40	4,74	149	364	598	831

Table 4.5: Maximum traffic load

Sectors	Theoretical resistance (K Ω)	Actual resistance (K Ω)	Actual S1/1/1 load	Actual S2/2/2 load	Actual S3/3/3 load	Actual S4/4/4 load
Sector 1	0	0	196	474	768	1068
Sector 2	0	0	196	474	768	1068
Sector 3	0	0	196	474	768	1068

The results for the sequence of rotation of the antennas following the command or condition of traffic load are summarized in Table 4.5.

Table 4.6: Rotating sequence

Command	Result
Sector 1 above max threshold	Sector 2 rotates to assist sector 1
Sector 2 above max threshold	Sector 3 rotates to assist sector 2
Sector 3 above max threshold	Sector 1 rotates to assist sector 3
Sector 1 above max threshold and sector 2 above min threshold	Sector 2 cannot rotate to assist sector 1 since it is above min threshold, but sector 3 rotates assist sector 2.
Sector 2 above max threshold and sector 3 above min threshold	Sector 3 cannot rotate to assist sector 2 since it is also above min threshold, but sector 1 rotates assist sector 3.
Sector 1 above max threshold and sector 3 above min threshold	Sector 1 cannot rotate to assist sector 3 since it is also above min threshold, but sector 2 rotates assist sector 1.
Sector 1, 2 and 3 above max threshold	No sector rotates since they are all above threshold values, an alarm is shown at the work station

4.2.2 Analysis

Looking at tables 4.2, 4.3 and 4.4 one can realize that the theoretical values of the potentiometer resistances differ from the actual readings, this may be due to internal noises within the circuit. Theoretical values are determined using ideal components, therefore coming up with the exact value will be a problem.

Table 4.4 shows the response of the sector antenna depending on which sector has gone above the maximum threshold traffic load. A sector antenna will only rotate if the load in that sector is below the minimum threshold value. If a sector antenna rotates to assist the other sector and if the traffic load of the sector that would have rotated goes above the maximum threshold value, it quits assisting and rotates back to its original sector position. For example, if sector 1 goes above the maximum threshold, sector 2 antenna rotates to assist sector 1, but if the traffic load in sector 2 increases above the maximum threshold then sector 2 antenna quits assisting sector 1 and rotates back to its original position. This is the reason why when all the sectors are above threshold values the sector antennas do not rotate to assist each other. At this point we

can say the base station is overloaded as it is operating at full capacity and RF engineers are alerted for them to come up with other RF optimization techniques.

This system is applicable to all wireless channel configurations (S1/1/1, S2/2/2, S3/3/3, S4/4/4), the threshold values are set specifically for each TRX configuration as shown in tables 4.2, 4.3 and 4.4. The S4/4/4 configuration has the highest traffic since it has more TRX per sector. S1/1/1 has the least traffic since it has one TRX per sector.

4.3 Questionnaire results and analysis

A group of four wireless engineers and one Radio optimization engineer at Huawei Technology Zimbabwe worked together to answer a questionnaire that was sent to them. The results showed that the system is feasible and can work with any broadband network. If the antenna type is changed the system will still be applicable but can only work with single band antennas as multiband antennas create difficulties in deciding whether the antenna should rotate in the expense of the other network bands.

The system does not affect the radiating capabilities of the antenna, therefore it does not affect the radiation pattern in any way. The power level and tilt angle affect the coverage area but the shape of the radiation pattern does not get distorted, the size is the one which is affected [1]. The structured questionnaire is attached in the appendix section.

REFERENCES

- [1] J. Vankka, Digital Synthesizers and Transmitters for Radio software, Chicago: Springer, 2005.

CHAPTER 5

CONCLUSION

5.1 Introduction

The automatic sector synthesis system for wireless base station antennas proved to be successful. This chapter gives conclusions and recommendations based on the results obtained as well as findings from the results and analysis.

5.2 Challenges

Every project bears challenges during implementation, in this project a few challenges were met.

Initially photodiodes were proposed to be used as sensors, but potentiometers were used instead. This change was influenced by the unavailability of electronic components at the college and in the city. The photodiodes were supposed to represent a traffic measuring sensor by sensing the level of light intensity and writing the result as analogue inputs to the microcontroller. The potentiometer worked quite well and helped bringing out the projects idea into reality.

The potentiometer in Sector 2 (pot 2) was not functioning well giving variable values on a single wiper position, thus writing wrong fluctuating values on the microcontroller. The LED and servo motor in this sector were continuously turning on and off. The potentiometer readings were causing system malfunction. A new functioning potentiometer was placed and the system started working properly.

Another challenge that was encountered include the breadboard connection which at times get lose and no input is realized at the Arduino microprocessor. Also some of the breadboard open spaces were continuous causing short circuits.

5.3 Recommendations

From the results, analysis and research done after the project implementation the following points where noted:

- (a) The system proved to be simple and cheap to install on base station tower, it just needs servo motors and software which can be embedded in the BBU applications of the APM30

cabinet, or a board which contains the system algorithms can be slotted in the base station cabinet.

- (b) The servo power system is connected on the ACDB inside the shelter and for an outdoor site it is connected on the ACDB point of the outdoor APM30 BTS cabinet.
- (c) Since the servo motors are positioned on top of the tower, they should be housed and installed just below the antennas.

5.4 Application areas of the system

This system involves sensors and actuators thus robot and robotics. It results in the movement of objects from one position to another therefore its general applications can be quite numerous, in telecommunications it can be used for:

- (a) Panning process in transmission microwave installation. Instead of having riggers panning the dish until they get the required matching receive signal power, servo motors can be installed on the microwave dish and power sensors installed on the LNB to scan for the power signal.
- (b) In satellite dish installations at earth centres and homes. The system can reposition the dish antennas if they are disturbed.

5.5 Limitations of the Automatic sector synthesis system

- (a) The system can work for single band antennas, working with multiband antennas may become complicated, for example if a 900/2100Mhz dual band antenna is used for sector 2, then the users of the 900Mhz band in sector 1 exceed above the threshold value and also the users of the 2100Mhz in sector 2 exceed the threshold, sector 2 is supposed to rotate and help sector 1 on the 900Mhz band, but it cannot because the 2100Mhz is above threshold it becomes difficult to use the system.
- (b) This system need a manual backup configuration system in the case that the servo motors break down, the system can be controlled from the switch room by the engineers on duty.

5.6 Further research

There has being little research and projects done in implementing robot and robotics technology in Zimbabwe. As mentioned above this system can be employable in other telecommunications installations and the use of this system might be helpful.

As a future work in the field of the presented project, we suggest developing the system for further RF optimization by adding tilt optimization, so on top the current azimuth optimization, tilt optimization should be included making the system more useful. Tilt optimization is an important parameter in controlling the radiation pattern area that is, coverage [1].

5.7 Conclusion

The prototype was a success as it was able to meet with all the objectives of the research. With the help of Huawei wireless engineers the system proved to be feasible and applicable in Zimbabwe's mobile networks. The automatic sector synthesis system tends to save resources of the network provider at the same time increase revenue. This system is the best for base stations located at Kopje, Rainbow Towers 1, Rainbow Towers 2, Harare showground because most events are held at the Robert Mugabe square and the sectors facing this area suffer congestion during these events therefore employing this system becomes helpful. This system is also recommended for base stations surrounding sports stadiums, large congregation churches because the sometimes they handle large a number of mobile users in sectors facing the gathering points.

REFERENCES

- [1] A. K. B. G. Sharma, "A Practical Approach to Improve GSM Network," *International Journal of Engineering and Advanced Technology (IJEAT)*, vol. 3, no. 4, p. 95, 2014.

APPENDIX 1

Software Algorithm

```
#include <Servo.h>      // adding servo motor libraries

Servo servo1;

Servo servo2;

Servo servo3;

const int kPinPot = A0;  // sector 1 potentiometer connected to analogue pin 0 of Arduino
const int kPinPot1 = A1; // sector 2 potentiometer connected to analogue pin 1 of Arduino
const int kPinPot2 = A2; // sector 3 potentiometer connected to analogue pin 2 of Arduino
const int kPinServo1 = 9; // sector 1 motor connected to digital pin 9 of Arduino
const int kPinServo2 = 8; // sector 2 motor connected to digital pin 8 of Arduino
const int kPinServo3 = 7; // sector 3 motor connected to digital pin 7 of Arduino

int led1= 10;           // sector 1 LED connected to digital pin 10
int led2= 11;           // sector 2 LED connected to digital pin 11
int led3= 12;           // sector 2 LED connected to digital pin 12
int led4= 6;            // Overload LED connected to digital pin 6

void setup()           // initial system setup
{
servo1.attach(kPinServo1);
servo2.attach(kPinServo2);
servo3.attach(kPinServo3);
pinMode(led1,OUTPUT);
pinMode(led2,OUTPUT);
pinMode(led3,OUTPUT);
pinMode(led4,OUTPUT);
}

void loop()
```

```
{
int val1 =analogRead(kPinPot);
  int val2 =analogRead(kPinPot1);
if (int val1 >= 500)
{
  digitalWrite(led1,HIGH);
}
else
{
  digitalWrite(led1,LOW);
}
  if (val1 >= 500 && val2 < 300)
  {
servo2.write(10);

  }
  else
  {
    servo2.write (0);
  }
  int val3 =analogRead(kPinPot2);
if (val2 >= 500)
{
digitalWrite(led2,HIGH);
}
else
{
```

```
digitalWrite(led2,LOW);
}
if (val2 >= 500 && val3 < 300)
{
servo3.write(10);
}
else
{
servo3.write (0);
}

if (val3 >=500)
{
digitalWrite(led3,HIGH);
}
else
{
digitalWrite(led3,LOW);
}
if (val3 >= 500 && val1<300}
{
servo1.write(10);
}
else
{
servo1.write (0);
}
```

```
if (val1 >= 500 && val2 >= 500 && val3 >= 500)
{
digitalWrite(led4,HIGH);
}
else
{
digitalWrite(led4,LOW);
}
}
```

APPENDIX 2



Questionnaire for Wireless engineering

Chiedza Constance Makatya is a student pursuing a Bsc honours degree in Telecommunications at the Midlands State University. She is carrying out a research in partial fulfilment of the requirements for her studies. The topic of her research follows:

Automatic Sector Synthesis System for Wireless Base Station Antenna based on Traffic Load

Project summary:

Besides adhering to the 0, 120, 240 degrees wireless antenna setup, the student is proposing for an antenna system that is able to position its antennas based on the traffic load in a sector. The system is going to be automatic, thus saving resources in terms of travelling expenses and rigging expenses and also increase safety of employees as there will be no need of climbing the towers frequently. These system also increase the company's revenue since much preference will be given to areas of hyper activity at any given time.

Kindly complete the attached questionnaire, any information contributions are kindly welcome.

Thank you.

Mobile
company.....
.....

1. Is the system feasible?

2. Can the system be suitable for all network bands?

