Radio Wave Signal Attenuation in a GSM Network (EPE as a Case Study).

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ABSTRACT

Radio waves are propagated from transmitting stations to receiving stations at different locations apart. As these signals propagate through the atmosphere they undergo reflection and refraction. This leads to degradation in the signal strength. The rate at which the signal degrades is called the attenuation constant. This work attempts to estimate the attenuation constant for GSM signal propagate from base stations within Epe town at 900 MHZ and 1800 MHZ bands. The attenuation constant of 900MHZ band was found to be 6.68db/km while that of 1800MHZ was 17.8db/km.

(Keywords**:** radio waves, attenuation constant, GSM, base station, propagation)

INTRODUCTION

The first cellular service was introduced in USA about 1946. Similar services followed in Europe soon after. The system was manually operated and has several disadvantages such as heavy and expensive terminals, restriction of service to coverage of a single transceiver site, availability of little frequency spectrum; as a result of the system was small and easily saturated and as congestion worsened, so did the quality of service.

During the 1950s and 60s, transistor technology was introduced enabling automation of the systems. No drastic change was experienced in the industry until the development of microprocessors in the 1970s. This new development facilitated large scale integrations and development of more computer systems. Cellular analogue technology was developed and launched in 1979. Bell laboratories in Chicago, IL developed AMPS (Advanced Mobile Phone System), closely followed by NMT (Nordic Mobile Telephone), and TACS (total Access Communications System in Europe.

From the early 1980s several European countries agreed that the existing analogue systems had serious limitations which include: the potential derma was more than the expected capacity of the system being used, the system did not offer compatibility (i.e., an NMT terminal could not access the TACS network and vice versa) and the development of a new cellular system would require hugely affordable capital outlay.

The Europeans realized this earlier and this led to the development of GSM. The development of GSM started in 1982, when the conference of European Posts and Telegraph (CEPT) formed a study Group Special Mobile (the initial meaning of GSM). The group was to study and develop a pan-European public cellular system in the 900MHZ range, using spectrum that had been previously allocated. At that time, there were many incompatible analog cellular systems in various European countries. Some of the basic criteria for their proposed system were: good subjective speech quality, low terminal and service cost, support for international roaming, ability to support hand held terminals, support for rang of new services and facilities, spectral efficiency and integrated service Digital Network (ISDN) compatibility.

In 1989, the responsibility for GSM was transferred to the European Telecommunications Standard Institute (ETSI) and the Phase 1 recommendations were published in 1990. At that time, the United Kingdom requested a specification based on GSM foe higher use densities with low power mobile stations and operating at 1.8HZ. The specifications for this system, called Digital Cellular System (DSC1800) were published in 1991. The first GSM trail run was conducted in 1991 while commercial services started in 1992. By the beginning of 1995, there 60 countries with operational or planned GSM network in Europe, the Middle East, Far East, Australia, Africa, and South America with a total of 5.4 Million subscribers.

GSM leads the world on the fastest showing most reliable and advanced digital technology available in the market place today. GSM provides integrated voicemail, high speed data, fax, paging and short message services capabilities. Today's GSM platform is hugely successful wireless technology and an unprecedented story for global achievement. In less than ten years since the first GSM network was commercially launched, it became the world's leading and fastest growing mobile standard, spanning over 200 countries. Today, GSM technology is in use by more than three in six of the world's populations and it is estimated that at the end of January 2007, there were over 1 billion GSM subscribers across more than 2000 countries of the world. The growth of GSM subscribers has increased by a staggering fold. It accounts for 73.0% of the world's digital market and 72.0% of the world's wireless market. The progress hasn't stopped there. Today's GSM platform is living, growing and evolving and already offer's an expanded and feature rich family of voice and data enabling services.

The development of GSM is the first step towards true personal communication system that will allow communication anywhere, anytime and with anyone.

EVOLUTION OF GLOBAL SYSTEM FOR MOBILECOMMUNICATION IN NIGERIA

When Nigeria gained her independence in 1960, there were only 18,724 functional telephone lines for an estimated population of 45 million, which was a "teledensity" ratio of 0.04 telephones per 100 people. During the thirty-odd years of military rule, there was very little by way of investment in telecommunications, and other sectors did not fare any better.

According to the International Telecommunication Union, by 1996 Nigeria's teledensity ratio was a mere 0.36.It rose slightly to 0.4 by 1999; according to the Nigeria Communication Commission (NCC). Nigeria's teledensity is a far cry from the African average of 1.67. Even the NCC admits that Nigeria has had a very limited telephone network for many years, and the waiting list is estimated at over 10 million people, who have applied to the incumbent monopoly, NITEL (established in 1985) for services. However, with the liberalization of the telecommunication industry in 2001, the story changed dramatically. The teledensity ratio had tripled within just one year of GSM operation.

By May 2005 Nigeria, with an estimated population of 128,771,988, had more than 9 million GSM subscribers, making the country one of the fastest growing GSM markets in the world. At the moment, there are four GSM operators in Nigeria: MTN V-Mobile, Glo Mobile and MTEL. MTN enjoys the greatest patronage, with over 4 million subscribers. It was predicted that between 2003 and 2006, Nigeria's GSM market would be Africa's fastest-growing mobile market, and this prediction had been fulfilled. The competition is getting fiercer by the day as operators have to compete desperately for the same potential subscribers.

Four years after the start of the GSM era in Nigeria, the focus is gradually shifting from providing coverage to providing quality service. The euphoria of owning a phone set is gradually giving way to complaints of dropped calls and congestion.

The operators are fast realizing that they are in a highly competitive environment where subscribers can make or break them. Dissatisfaction by subscribers gives rise to a high rate of subscriber churn and low revenue for the operator. The performance of the network has a direct impact on the revenues. The NCC is bringing pressure to the operators to step up the quality of service offered Nigerians and had even gone a step further to award contracts to private companies to conduct comparative analyses of the quality of service offered by each of the operators. The NCC is further threatening to sanction any operator that fails to pay attention to quality.

It therefore behooves all the operators to ensure that the subscribers enjoy the best of service. The determining factors that produce customer satisfaction are answered by these three questions:

- Can the call be made (or received)?
- What will it sound like?
- Will the call drop?

THE GLOBAL SYSTEM IN NIGERIA

August 2001 was a pivotal date in the history of Nigeria. That was when the first Global System for Mobile (GSM) communications call was made under a democratic government. This event heralded the dawn of a new era the era of GSM technology, which has completely changed the face of doing business in Nigeria. It was also in August 2001, that Econet and MTN launched commercial operations while NITEL also commenced digital mobile operations about a month afterwards through her full owned subsidiary M-TEL. This was thus opened to competition with consumers having a broad range of options for network access and product offerings. Within nine months of the commencement of operations, the mobile operators had exceeded their business plan projections for subscribers by nearly double. Nigeria joined the league of countries with GSM mobile access in Africa and grew teledensity by over 350% within months of network activation.

Nigeria has risen to become one of the fastest growing telecoms market in the world. Mobile phones are now available to residents previously without telephone access and are growing at a much faster rate than the fixed line network. The telephone access is growing at a much faster than the fixed line network. The general trend is towards fixed mobile substitution where subscribers are using mobile lines as substitutes for non-available or relatively expensive fixed lines.

However, four years after the first GSM call was made, the GSM industry in Nigeria has changed a lot. Competition for subscribers is getting fierce. Operators have resorted to "price wars" to win subscribers. Subscribers, on the other hand, have more choices than ever regarding which GSM operator to use. To attract, maintain and move subscribers to high-value services such as voice, network operators must provide an unprecedented quality of service. Providing quality service will require monitoring and quality assurance with a view to optimizing the network.

The network statistics captured in the switch are monitored and processed at the Network Monitoring Center (NMC), using network monitoring tools that are based on the traditional row-column format. However intelligent these tools are; they only provide information on what is happening and very little on where. Field engineers who usually fix problems affecting the network have to depend on their intuitive wet knowledge to understand where the subscribers are experiencing low service quality.

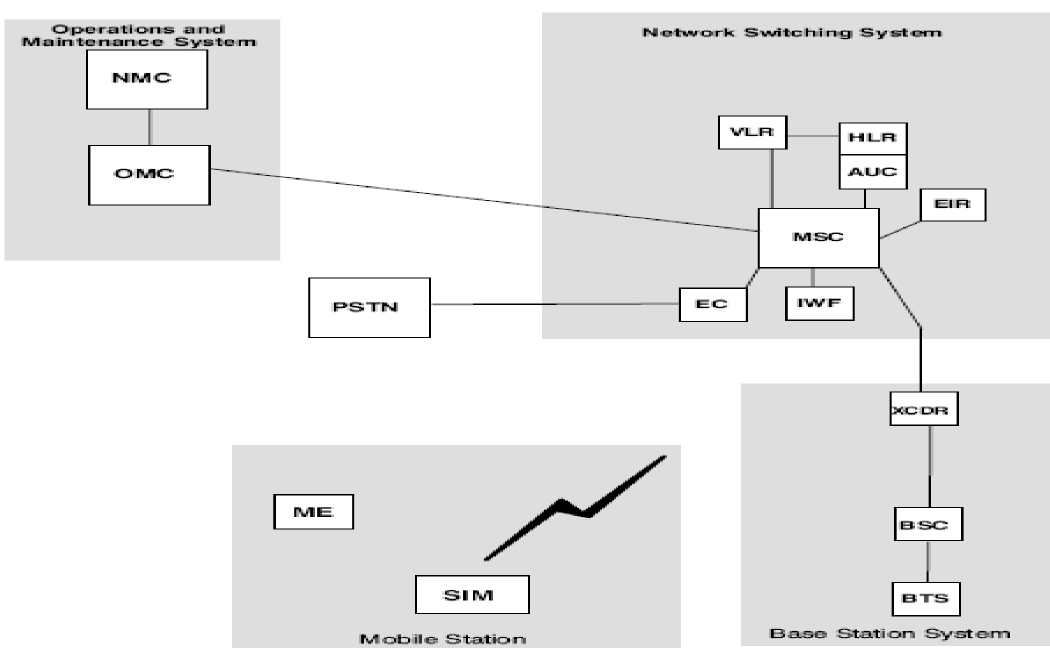

Figure 1: GSM Architecture.

GSM Physical Channels

A single GSM RF carrier can support up to eight MS subscribers simultaneously. Physical channels is all the TS of the BTS, either full rate (13kbps) or half rate(6.5kbps). The diagram opposite shows how this is accomplished. Each channel occupies the carrier for one eighth of the time. This is a technique called Time Division Multiple Access.

GSM Traffic Channels (TCH)

The traffic channel carries speech or data information. The different types of traffic channel are listed below:

- **Full rate** _ TCH/FS: Speech (13 kbit/s net, 22.8 kbit/s gross)
- **Half rate**_ TCH/HS: speech (6.5 kbit/s net, 11.4 kbit/s gross)

GSM Control Channels

These are Broadcast Control Channel (BCCH), Common Control Channel (CCCH) and Dedicated Control Channel (DCCH).

RESEARCH METHODOLOGY AND DATA COLLECTION

This project involves obtaining the mean receive power distribution at specified receiver distances of 0.5km interval from 0.5km to 10km from the respective Test GSM stations.

Measurements were taken for five different GSM base transceiver station at Epe town, eastern axis of Lagos State, Nigeria. The test was taken for both 900MHz and 1800MHz bands.

The field measurements were obtained by using 14dBi Sony Ericsson mobile station as test phones. Different parameters including receive power levels can be obtained from the debug screen of the mobile station.

The receive levels were taken at the specified distances from each sector of the sites under test. The mean receive levels for each of the sites were obtained for the five different sites for both 900MHz and 1800MHz.

From the data obtained, the attenuation constants were obtained for each of the test sites at different frequency bands.

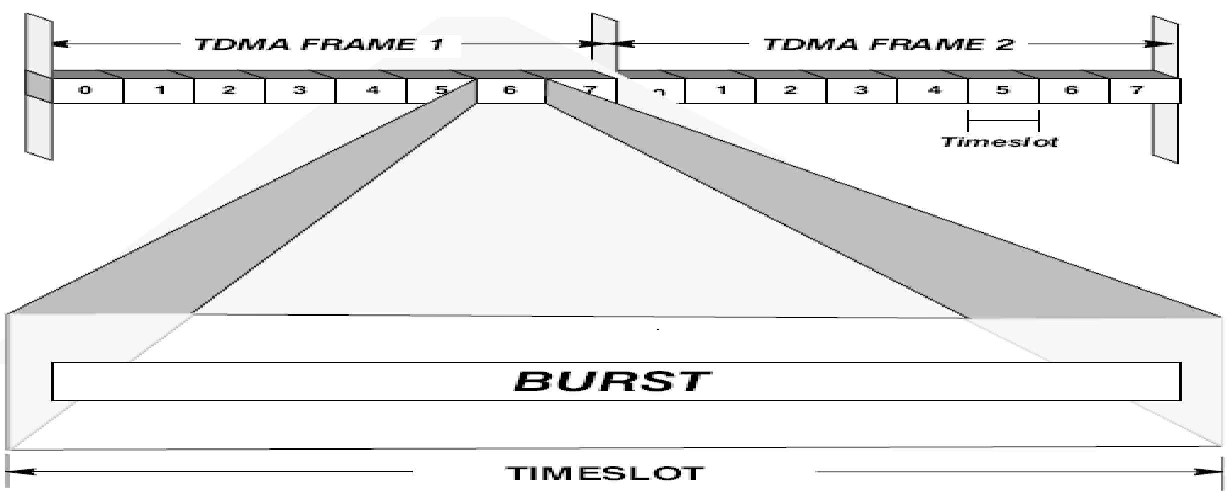

Figure 2: GSM Physical Channel.

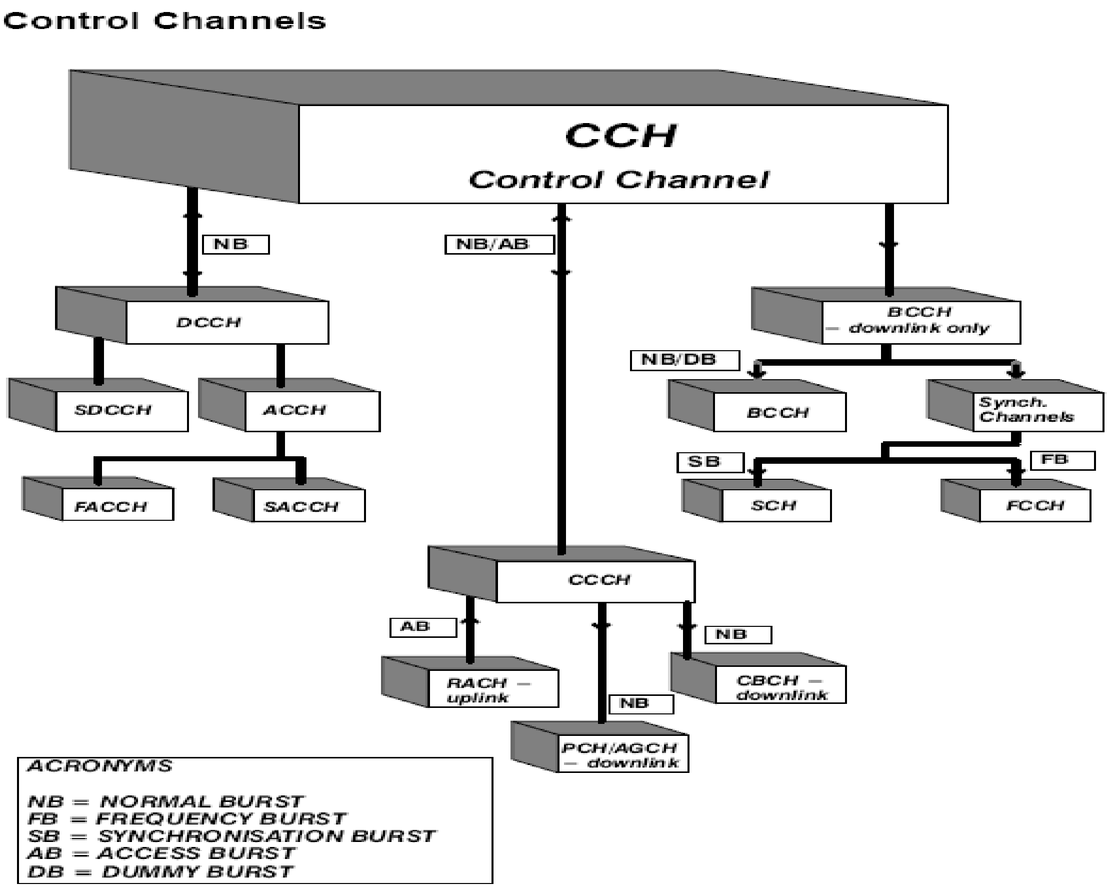

Figure 3: GSM Control Channels.

THE INVESTIGATED ENVIRONMENTS

This experiment was carried out at different locations within Epe town of Lagos State, South-West of Nigeria. Tests were carried out within a total of five sites. The figure below is a picture of one of the test sites.

Figure 4: Image of one of the site used.

The base station used for this experiment were properly selected at different locations within Epe town to give a thorough experimental exercise. The figure below shows a site layout of the sites under test. This layout was plotted using Map Info software 7.0 .

EXPERIMENTAL SETUP

This simple but very comprehensive experiment was carried out using simple tools. These tools include the following:

1. Sony Ericsson mobile station with 14dBi antenna
2. A piece of compass
3. A global positioning system GPS

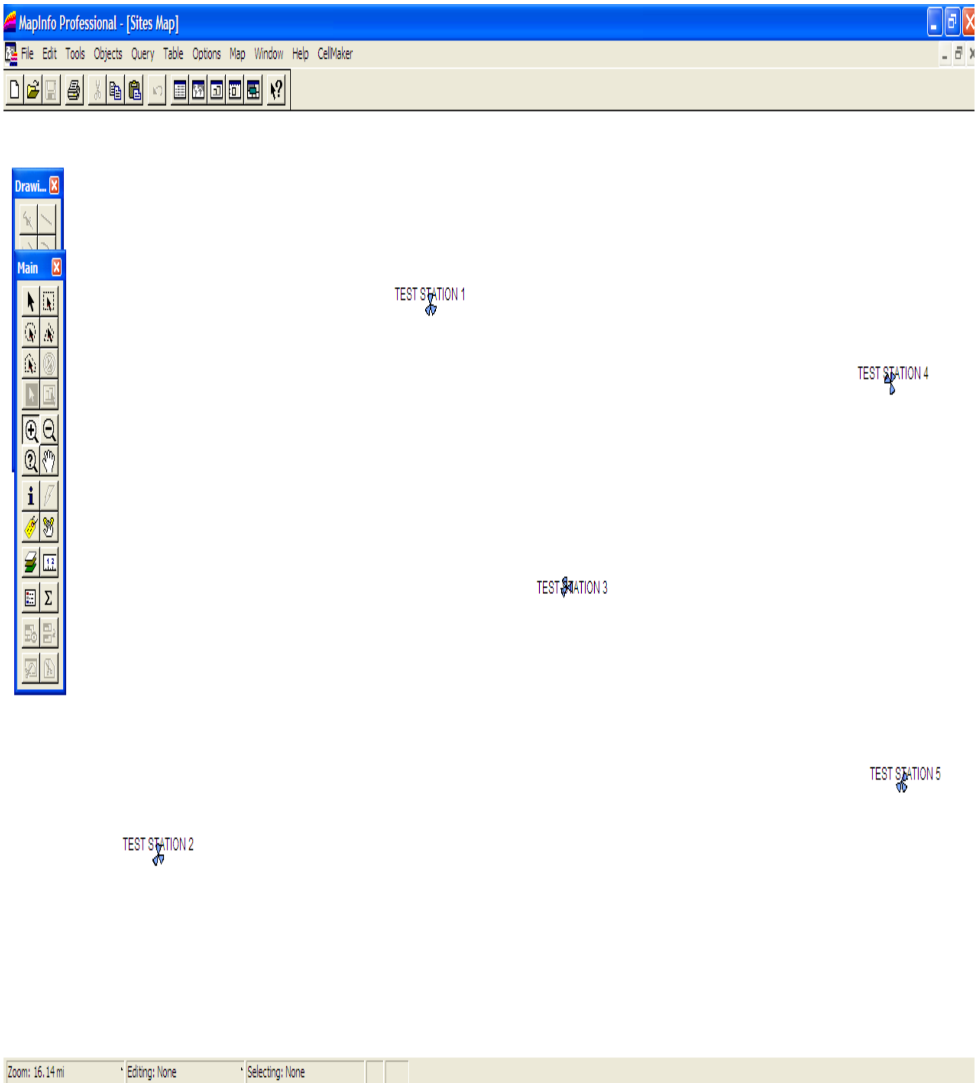

Figure 5: Map Info Software.

SITE ID	LONG	LAT	AZ	BW	RMKS
TEST STATION 1	3.792104	6.639164	0	65	
TEST STATION 1	3.792104	6.639164	130	65	
TEST STATION 1	3.792104	6.639164	220	65	
TEST STATION 2	3.726545	6.56793	10	65	
TEST STATION 2	3.726545	6.56793	120	65	
TEST STATION 2	3.726545	6.56793	220	65	
TEST STATION 3	3.824883	6.602529	90	65	
TEST STATION 3	3.824883	6.602529	240	65	
TEST STATION 3	3.824883	6.602529	330	65	
TEST STATION 4	3.902734	6.628987	30	65	
TEST STATION 4	3.902734	6.628987	160	65	
TEST STATION 4	3.902734	6.628987	300	65	
TEST STATION 5	3.905466	6.577428	50	65	
TEST STATION 5	3.905466	6.577428	140	65	
TEST STATION 5	3.905466	6.577428	230	65	

SONY ERICSSON MOBILE STATION WITH 14DBI ANTENNA

The mobile station measures the receive power levels at different location from each of the base stations under test.

A PIECE OF COMPASS

A piece of compass is a device which is used to measure the angular orientation of objects with respect to the true north which is referenced as 0 degree. In this project, the compass was used to measure the orientation of radio frequency antennas for each of the sites under investigation. As one moves away from the test sites, orientation of the test engineer with respect to the antenna changes. The compass helps the engineer to be within the orientation of the main lobe of the antenna. The figure below shows a simple compass used for the experiment.

Figure 5: Experimental Compass.

GLOBAL POSITIONING SATELLITE GPS SYSTEM

The GPS system is a location tracking device. It operates with Global Positioning Satellite for location tracking. The GPS device displays locations on its screen in different formats including longitude and latitude. The GPS also measures the velocity of a body on which it is placed. The GPS also measures the distance of a location from a reference location.

For this experiment, the GPS was used to track the location of each the sites under test. It is also used to measure the receiver distance from reference base stations.

DATA COLLECTION

Data collection was done starting from a distance of about 500meters from the base station. This was done for each of the sectors of the test sites. All the sites under test were dual band sites. That is, each consists of both 900 MHz and 1800 MHz band. The receive level distribution was collected and presented for both bands.

Receive level distribution were collected for each of the three sectors of the base station. The mean receive level for each site was then obtained. The table below shows the receive level distribution as collected from the first test site used for this experiment.

Table 1: Experimental Table for Receive Level Distribution.

	MEAN RECEIVE LEVEL(dBm) of TEST SITE 1			MEAN RECEIVE LEVEL(dBm) TEST SITE 1		
	900Mhz band			1800Mhz band		
Receiver Distance (Km)	SECTOR 1	SECTOR 2	SECTOR 3	SECTOR 1	SECTOR 2	SECTOR 3
0.5Km	-48	-51	-45	-58	-60	-57
1.0Km	-50	-52	-49	-63	-64	-64
1.5Km	-53	-54	-53	-68	-69	-68
2.0Km	-56	-57	-57	-75	-75	-75
2.5Km	-60	-61	-61	-81	-83	-85
3.0Km	-62	-64	-65	-86	-86	-86
4.0Km	-66	-66	-70	-80	-82	-89
4.5Km	-69	-67	-74	-84	-84	-84
5.0Km	-73	-70	-79	-89	-89	-89
5.5Km	-76	-75	-83	-92	-90	-91
6.0Km	-80	-81	-88	-98	-98	-98
6.5Km	-83	-83	-94	-98	-98	-98
7.0Km	-88	-87	-98	-106	-108	-105
7.5Km	-92	-90	-101	-113	-116	-114
8.0Km	-96	-93	-104	-110	-111	-110
8.5Km	-98	-97	-108	-120	-120	-120
9.0Km	-104	-99	-110	-106	-106	-107
9.5Km	-107	-104	-112	-108	-108	-108
10.0Km	-110	-105	-115	-119	-118	-116

DATA ANALYSIS

From the data obtained above for the receive level distribution, the mean receive level was obtained. This was done for each of the test base stations under 900MHz and 1800MHz bands.

The table below presents the mean receive levels obtained for all the five test sites for 900MHz.

Table 2: Mean Receive Level.

	MEAN RECEIVE LEVEL (dBm) of ALL TEST SITES				
	900MHz BAND				
Receiver Distance (Km)	Test Site 1	Test Site 2	Test Site 3	Test Site 4	Test Site 5
0.5Km	-44	-46	-52	-48	-45
1.0Km	-48	-50	-55	-51	-49
1.5Km	-56	-52	-57	-54	-54
2.0Km	-59	-61	-60	-58	-60
2.5Km	-65	-63	-63	-61	-64
3.0Km	-68	-68	-67	-64	-68
4.0Km	-75	-71	-70	-67	-73
4.5Km	-75	-77	-72	-71	-76
5.0Km	-82	-78	-74	-75	-80
5.5Km	-81	-85	-77	-78	-83
6.0Km	-89	-85	-81	-81	-87
6.5Km	-90	-90	-83	-84	-90
7.0Km	-95	-91	-86	-88	-93
7.5Km	-97	-105	-88	-90	-96
8.0Km	-98	-98	-90	-91	-98
8.5Km	-100	-100	-91	-93	-100
9.0Km	-106	-102	-93	-95	104
9.5Km	-109	-109	-103	-99	-109
10.0Km	-110	-120	-108	-104	-115

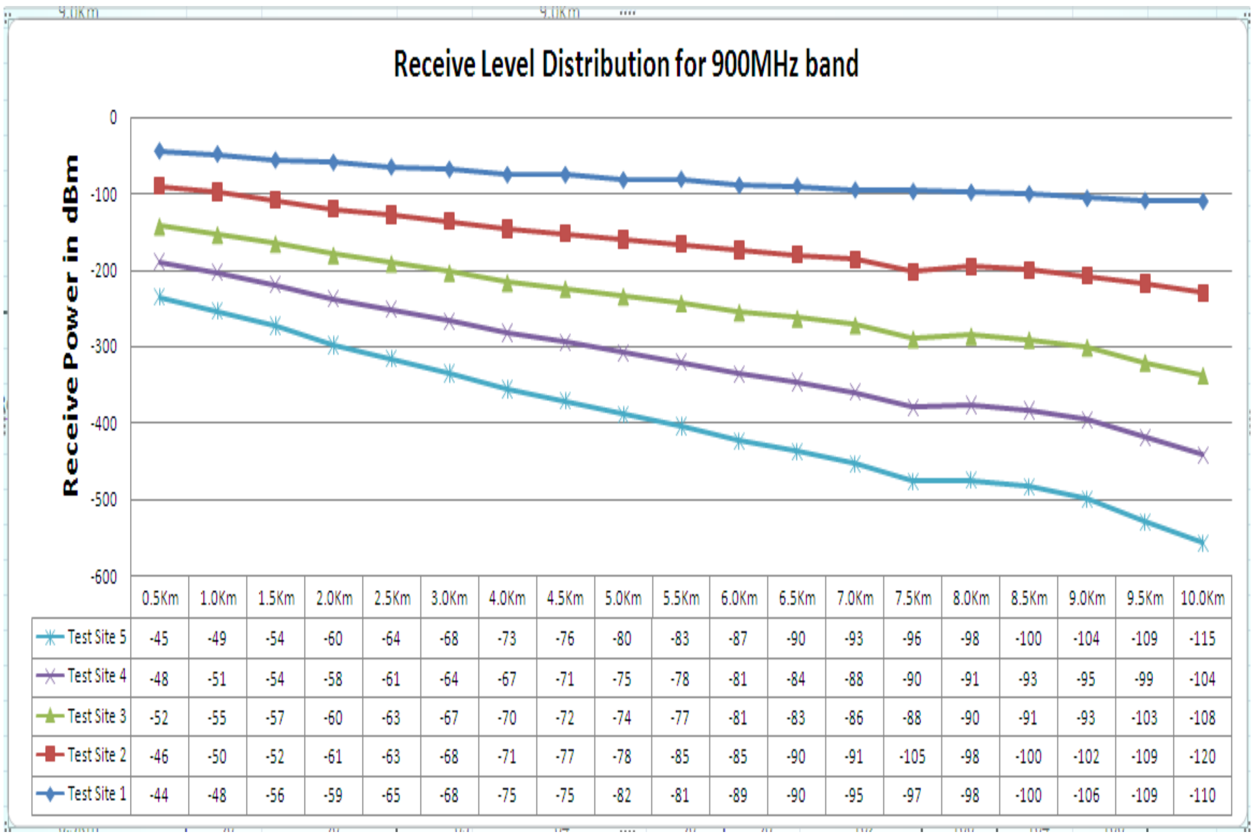

Figure 6: Receive Level Distribution.

The graph above shows a graphical representation of the receive level distribution. The slope of the graph will then be calculated. This slope gives the attenuation rate or attenuation constant for the sites under test.

Attenuation constant = Change in Receive level (dBm) / Change in distance(Km).

The table below presents the mean receive levels obtained for all the five test sites for 1800MHz.

Table 3: Mean Receive Level.

	MEAN RECEIVE LEVEL (dBm) of ALL TEST SITES				
	1800MHz BAND				
Receiver Distance (Km)	Test Site 1	Test Site 2	Test Site 3	Test Site 4	Test Site 5
0.5Km	-58	-54	-56	-56	-58
1.0Km	-64	-60	-62	-68	-68
1.5Km	-68	-70	-69	-72	-74
2.0Km	-75	-75	-75	-79	-75
2.5Km	-82	-80	-81	-81	-79
3.0Km	-86	-80	-83	-80	-88
4.0Km	-80	-88	-84	-90	-86
4.5Km	-84	-88	-86	-90	-94
5.0Km	-89	-89	-89	-96	-96
5.5Km	-91	-93	-92	-104	-100
6.0Km	-98	-94	-96	-101	-106
6.5Km	-98	-102	-100	-104	-100
7.0Km	-106	-104	-103	-112	-100
7.5Km	-114	-100	-107	-101	-113
8.0Km	-110	-108	-109	-106	-110
8.5Km	-120	-102	-111	-112	-108
9.0Km	-106	-120	-113	-108	-114
9.5Km	-108	-120	-114	-118	-112
10.0Km	-117	-113	-115	-118	-116

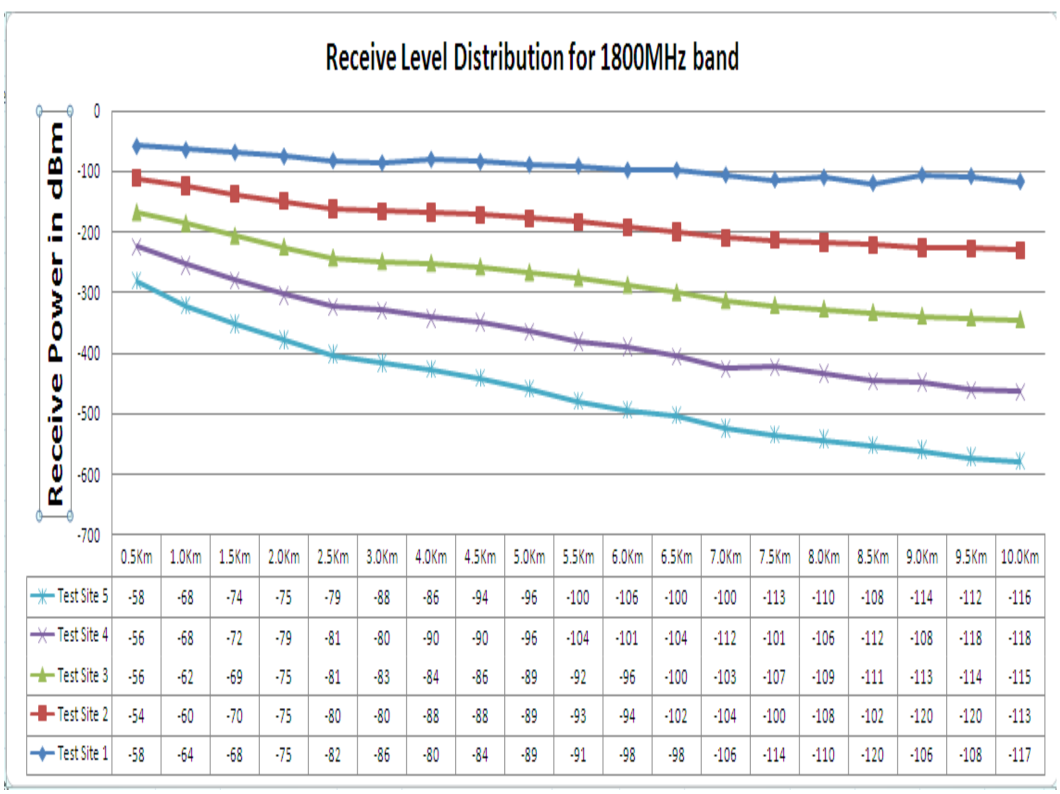

Figure 7: Receive Level Distribution.

RESULTS OBTAINED

The result of this test shows different attenuation constants for the five test sites under test. The table below represents the attenuation constant for the 900MHz band.

Test Site	Attenuation Constant (dBm/Km
1	7.51
2	8.42
3	5.14
4	5.78
5	6.57

For the 900MHz band, attenuation constant was obtained to be 6.68.

For the 1800MHz band, the attenuation constant is as tabulated below:

Test Site	Attenuation Constant (dBm/Km
1	18
2	17
3	18
4	16
5	20

For the 1800MHz band, attenuation constant was obtained to be 17.8

CONCLUSION

The aim of this work is to calculate attenuation constant or attenuation rates for five sites which were the randomly chosen sites for the experiments.It is therefore concluded that from the result obtained, the attenuation constant for 1800MHZ was higher than that of 900MHZ band.This further proves the theory between frequency and coverage or wavelength, that is the lower the frequency the larger the coverage area (i.e., velocity=wavelength x frequency).

RECOMMENDATIONS

This model for attenuation constant was estimated using GSM based stations. It is therefore recommended that this model should be validated for CDMA and other cellular networks.
Proper site verification exercise should be carried out on all test sites to ensure all sites are free of critical alarms/faults before carrying out the experiments.

This experiment should be carried out with more number of test stations in order to obtain improved experimental results accuracy.

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