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# Technical Performance Analysis of AMPS vs. TDMA Wireless Cellular System Design based on Telecom Mobile Company budget

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***Abstract: -*** *Telecommunication is one of the integral parts of science that has always been a focus point for exchanging information among parties at locations. The term `mobile' has completely revolutionized the communication by opening up innovative applications that are limited to one's imagination. Today, mobile communication has become the backbone of the society and is spreading very fast when the government throughout the world provided radio spectrum licenses for Personal Communication Service (PCS) in 1.8 - 2 GHz frequency band. The first generation networks in the market were AMPS (Advanced Mobile Phone System) deployed in Chicago in 1983. The main technology of this first generation mobile system was AMPS. However, the second generation networks based on Digital modulation formats that were introduced in this generation with the main technology as TDMA (Time Division Multiple Access). In this research paper, we assume our company name as Telecom Mobile Company has a budget of $20 million with the population of 850, 000 users that can be affording only 33 cells where the cluster size is 7. Therefore, each cell costs about $250,000 and each user channel in the cell site costs to $1000. The cluster having 395 voice channels, so the number of channel per cell can be 395/7=56 channels in a Hexagonal Cell Structure. The calculation work is done such as coverage area, distance, signal to interference ratio, Receiver Sensitivity, Noise Density, Path loss, Okumura model, etc. for AMPS and TDMA design based on Telecom Mobile Company's budget. From this paper, TDMA is the efficient utilization of hierarchical cell structures that allows coverage for the system to be tailored to support specific traffic and service needs whereas AMPS is not very efficient. From cellular system designing, consequently TDMA offers a flexible air interface, providing high performance with respect to capacity, coverage, and unlimited support of mobility and capability to handle different types of user needs. In AMPS, each user can access a channel on a continuous time basis according where TDMA provides the voice conversation that allows more users to carry a secured conversation on the same channel as users were assigned different time slots. Moreover, the designing approach for AMPS and TDMA is same except that in TDMA, each channel is shared by 3 different user in hexagonal cell on Telecom Mobile Company budget based on our assumptions.*

**Keywords:** AMPS, TDMA, Hexagonal Cell, Signal-to-Interference, Noise Density, Receiver Sensitivity, Path loss, Okumura Model

# 1. Introduction

## AMPS:

AMPS is an acronym of Advanced Mobile Phone System. This kind of cellular system technology deployed in early 1980's in North America. In 1988 10 MHz additional bandwidth was allocated to AMPS which was developed in Chicago, with coverage area of 2100 square miles [4]. It is an analog voice only system. However, AMPS uses analog Frequency Multiplexing with a peak frequency deviation of 5 KHz and Frequency Division Multiple Access too. The basic idea behind AMPS designing is:

(1)Frequency Division Duplexing is used for simultaneous two way conversations, which is as:

(a) Outbound transmission (Base Station to Mobile) occupies the band 870-890 MHz

(b) Inbound transmission (Mobile to Base Station) occupies the band 825-845 MHz

(2) Frequency Division Multiple Access (FDMA), is used to support multiple users in a cell or cell sector.

The AMPS system was frequency modulation radio system using frequency division multiple access (FDMA) with channel capacity of 30 KHz and frequency band was 824-894 MHz [3]. In the AMPS scheme, each user is assigned a unique 30 kHz bandwidth channel for a single cellular phone call. The area coverage is divided into Honeycomb-type cells or Honey-Bee cell diagram and the cells overlap each other at the outer boundary. Consequently, frequencies are divided into cells or sectors to prevent co-channel and adjacent channel interference. Hence, the more users who subscribe to a network, then the closer the transmitters are placed to each other. AMPS and TACS use the frequency modulation (FM) technique for radio transmission. Traffic is multiplexed onto an FDMA (frequency division multiple access) system [5, 1].

## TDMA:

TDMA (Time Division Multiple Access), a digital 2nd generation cellular system technology that allows users to share a single carrier frequency channel with multiple users. Many more designing scenarios have developed with not only 2G networks but also with the evolution of 2G to 2.5G or even to 3G networks. Along with this, inter-operability of the networks has to be considered [2]. TDMA systems have the capability to split users into time slots because they transfer digital data, instead of analog data commonly used in legacy FDMA systems. TDMA have no fixed assignment of frequencies to control channels. Moreover, TDMA spectral efficiency is in terms of voice calls and it is about 3 times better than AMPS. TDMA systems do not transmit all of the time; their mobile phones have an extended battery life and talk time. TDMA is also used for Digital Enhanced Cordless Telecommunications. The problem with TDMA is Multipath Distortion from either Path (P1) or Path (P2), but one way of getting around this interference is to put a time limit on the system as looking in this figure1.

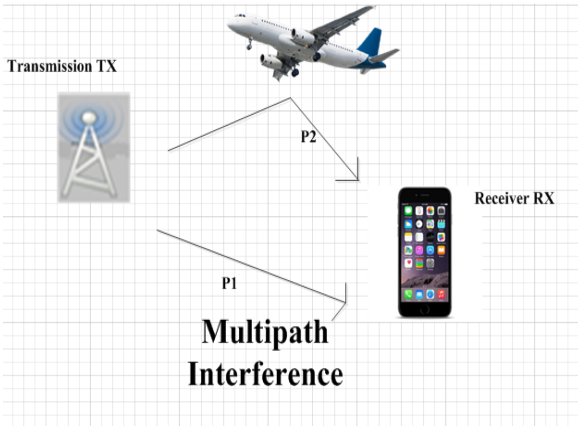


**Figure 1 Multipath Distortion**

Table 1 summarizes the generations of wireless technology.

| Generation | Requirements | Comments |
|---|---|---|
| 1G | No official requirements. Analog technology. | Deployed in the 1980s. |
| 2G | No official requirements. Digital Technology. | First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA and GSM. |
| 3G | ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors | Primary technologies include CDMA2000 1X/ EVDO and UMTS-HSPA. WiMAX now an official 3G technology. |
| 4G | ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency. | No technology meets requirements today. IEEE 802.16m and LTE-Advanced being designed to meet requirements. |

**Table 1 1G to 4G [6]**

## 2. Telecom Mobile Company's Requirement for AMPS and TDMA Designing of hexagonal cell

We assume our company name as Telecom Mobile Company has a budget of $20 million and each cell costs=$250,000. However, each user channel in the cell site costs=$1000. Since there are 56 channels per cell, so cost of cell site=$250,000+$1000*56=$306,000

Cell sites that can be afforded by company is 32.7, which is approximately equal to 33 cells

In our design, Telecom Mobile Company is using cluster of 7 cells. Therefore, cluster having 395 voice channels as looking in the above figure2. So, the number of channel per cell can be 395/7=56 channels.

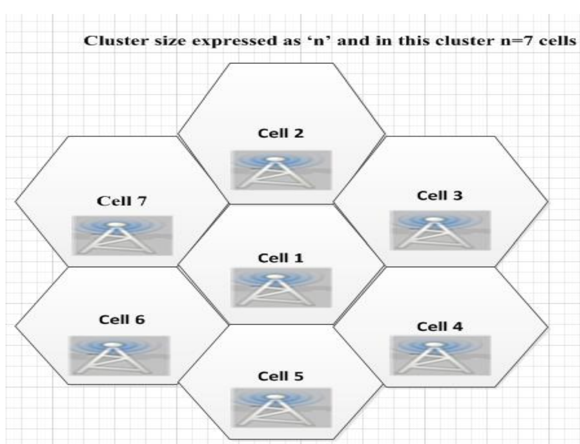


**Figure 2 Hexagonal cell structure design on Telecom Mobile Company budget**

## 3. Designing Approach and Structure for AMPS and TDMA Design of Telecom Mobile Company

(1) The designing approach for AMPS and TDMA for Telecom Mobile Company is same except that in TDMA, each channel is shared by 3 different users.
(2) TDMA increases the capacity by three times greater than the AMPS.
(3) The area coverage is divided into Hexagonal Cell diagram for both approaches and cells overlap each other at the outer boundary.
(4) Prevent co-channel and adjacent channel interference when frequencies are divided into cells are shown in figure.3.

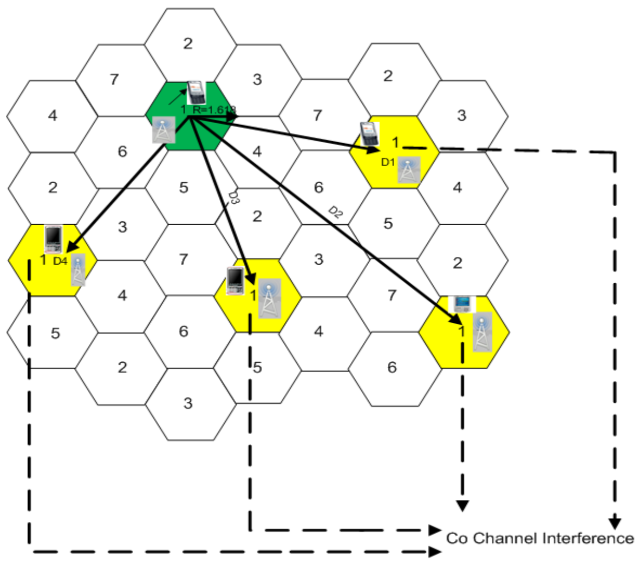


**Figure 3 AMPS and TDMA hexagonal design structure on Telecom Mobile Company budget**

The AMPS and TDMA design structure of Telecom Mobile Company is shown in figure 3. Where 1 in the Green color Hexagonal Cell is the Reference Channel(R) with Radius =1.618 miles. Other Hexagonal Cell 1 with yellow color having Distance D1, D2, D3, and, D4 are Co-Channel Interference.

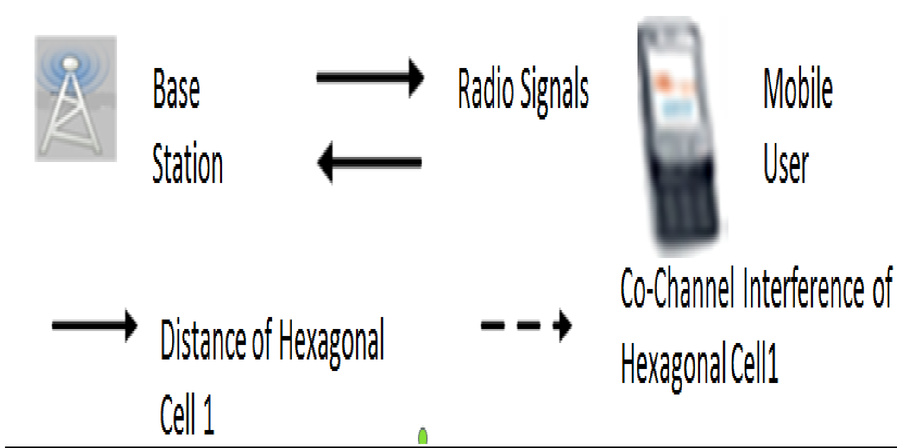


**Figure 4 Symbol representations on figure 3 hexagonal cell structure**

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## 4. Designing Structure and Calculation of AMPS Cellular System Design

### I. AMPS Cellular System Design:

With the population of 850,000 users based on Telecom Mobile Company budget and cells that have it on a hexagonal cell structure measures 15 miles on each side. So, it means that for a normal operation, cell site may be separated by 15 miles. If this problem affects our AMPS design, then a cell can be subdivided into smaller cells and reallocating frequencies for continued use. Consequently, the smaller the cell, the more equipment and other components are necessary. Moreover, it places an added financial burden on the carriers as they attempt to match customer needs with returns on investments. In short, the mode of operation of a cell is determined by the type of antenna used to support the air interface between the cell site and the mobile phone. In our AMPS design, Omni-directional antenna is used. We assume that cell site costs $250,000 and each user channel in the cell in the cell site costs an additional $1000. However, the cell site serves a single 360-degree area around itself. When interference reaches unacceptable levels, the site is usually sectorized to reduce co-channel interference. The allocation of frequencies based on AMPS designed around 416 duplex channels per operator. But only 395 channels are used for voice transmission and remaining 21 channels are used as control channel. We assume that the frequency ranges for cellular spectrum were allocated in the 850 MHz and in each band, the channels use a 30 kHz bandwidth. In AMPS, no one can use the frequency until the conversation be complete, whether or not the parties were actually talking. When the conversation is completed, the first pair of people would leave and another pair would then be able to enter.

### II. Assumptions for Design & Calculation of AMPS:

**(a)AMPS Hexagonal Cell Structure for number of users/mobiles per channel and traffic covered:**
(1)Population of 850,000
(2)In our assumption, cluster having 7 cells for AMPS design. Number of channels per cell=395/7=56 channels.
(3)Traffic intensity per user=2/60=0.03 Erlangs
(4)Blocking Probability (GOS)=0.02
(5)Total carried traffic for 56 channels per cell=45.88 Erlangs
(6)Number of Users that can be supported per cell=45.88/0.03=1529 users
(7)Since there are 33 cells, Maximum carried traffic=Number of cells*traffic intensity per cell
Therefore, Maximum Carried Traffic=33*45.88=1514.04 erlangs
(8)Total number of users that can be supported by the system=Maximum Carried Traffic/Traffic intensity per user=1514.04/0.03=50468 users
(9)Number of mobiles per channel=Total number of users that can be supported by the system/Traffic intensity per user=50468/395=128 mobiles per channel

**(b)Coverage Area for AMPS**:
Total coverage area=225 (15*15) sq miles
Company can afford only 33 cells
Area covered by each cell=A=225/33=6.82 sq miles
As, $A=2.6*(R^2)$, Therefore, Radius of cell=R=1.618 miles
**(c)Distance and S/I for AMPS:**
The distance between the mobile and the interfering base station is approximately for I user is:
$D=\sqrt{((i)^2+(j)^2+ij)}\,\sqrt{3}R$
Where i=1, and j=2, R=1.6445 in the cell design structure for AMPS
**D**$=\sqrt{((1)^2+(2)^2+(1)(2))}\,\sqrt{3}*1.618=7.42$ miles

Signal to Interference and Noise Ratio (SINR) value is an essential metric in the link budget analysis, and it can be used for evaluating the achievable cell throughput, or from other perspective a target. SINR value can be set to plan the network so that the desired throughput value can be achieved. [7].

**Signal-to-Interference Ratio=**$\left(\frac{S}{I}\right)=\frac{\sqrt[4]{3*N}}{6}=\sqrt[4]{21}/6$=93.5 watts=18.66dB

**(d)Allowable Path loss for AMPS Design is:**

Assume: 8.5dB Cable Loss

$P_T$=44 watts=16.4dBW

Transmitter Antenna Gain =$G_T$=19.2 dB

Receiver Antenna Gain = $G_R$=1 watts=0 dB

**Allowable Path loss=Cell Site Transmit Power(EIRP)** = $P_T + G_T$ – Cable loss =27.1 dBW=513 watts

**(e)Okumura Model for AMPS Design:**

(i)As, R=1.618 miles, so I mile=1.6093 km and Therefore 1.644 miles=2.65 km

Let λ=0.3529 meters

$\lambda^2$=0.124567 meters

$L_p$ (Path Loss)=10log[((4∏)$^2$ * (R)$^2$)/((λ)$^2$)]

Hence **Lp**=10log [((4∏)$^2$ * (2.65K)$^2$)/0.1111]=99.32dB

Therefore, **R**=2.65 km

(ii)Let A(f,d)=20dB, Gain Area=9dB, Transmitter Height=200 meters, Receiver Height=3 meters

Therefore, **Gain of Height Transmitter**=20log(200/200)=0dB

**Gain of Height**

**Receiver**=20log(3/3)=0dB

**(iii)Okumura Model** defined as:

L(dB)=$L_p$ + A(f,d) **-** Gain of Height Transmitter **-** Gain of Height Receiver – Gain Area

**L(dB)**=99.32+20-0-0-9=110.32dB

**(f)The Received Power for AMPS Design:**

$P_R$=Allowable Path loss-L

$P_R$=27.1dBW-110.32dB= -83.2dB

**(g)Noise Density(N), $\frac{S}{N}$ and $S_{min}$ for AMPS Design:**

The noise level at the receiver in the downlink and uplink directions depends on the cell loading in hexagonal structure [8].

**Noise Figure**=8dB, Bandwidth=B=30KHz

**N=F*( $KT_o$)*B**

N (dBM) =K(dBm) + $T_o$ + F + B (dB) Hz

N(dBm)=198.6+10$\log_{10}$290+8+10$\log_{10}$30000

**Noise Density 'N' (dBM)**=-121.205dBm=7.577*$10^{-16}$ Watts

$S_{min}$ = EIRP + $G_R$ - L

**(Receiver Sensitivity)$S_{min}$ = 27.1+0-110.32= -83.2 dBW = -53.2 dBmW**

**Note: However, Receiver Sensitivity is same as Received Power as in AMPS design.**

$\left(\frac{S}{N}\right)$ ***(Signal to Noise Ratio)*** **= $S_{min}$ - N**

$\left(\frac{S}{N}\right)$ = -53.2-(-121.205)=68.005 dB

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## 5. Designing Structure and Calculation of TDMA Cellular System

### I. TDMA Cellular System Design:

In TDMA design, using the same population of 850,000 on Telecom Mobile Company budget that measures 15 miles on each side. So, it means that for a normal operation, cell site may be separated by 15 miles. In our AMPS design, Omni-directional antenna is used. We assume that cell site costs $250,000 and each user channel in the cell in the cell site costs an additional $1000. Although TDMA design have 30 KHz bandwidth, 6 slots per frame allowing three users and each user having 2 slots at 40msec frame. Therefore, TDMA have 324 bits per slot. Moreover, TDDMA design have a transmit band for 800MHz base station is 869-894MHz and the mobile transmit frequency is 824-849 MHz In TDMA environment, each of the frequencies would be able to accommodate multiple conversations simultaneously. As in the figure4, with a three-slot TDMA system, it contains of three pairs of people, with the different pairs taking turns talking as shown in figure 5. According to this system, each pair can speak for 20 seconds during each minute.

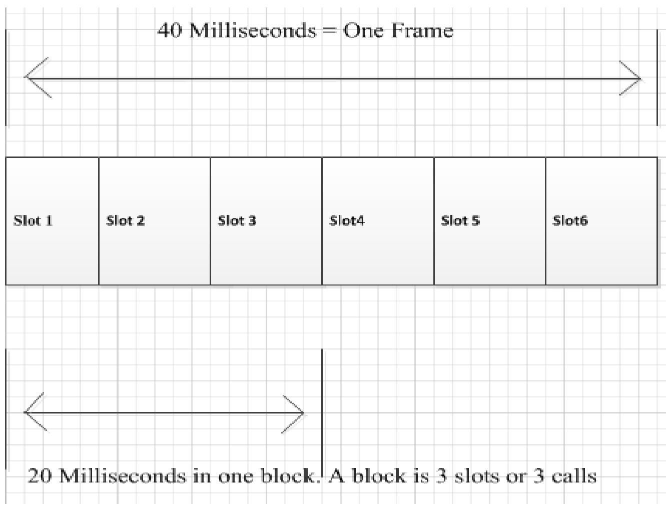


**Figure 5 TDMA time slots**

When we look at the TDMA Design Structure as in figure 6 i.e.

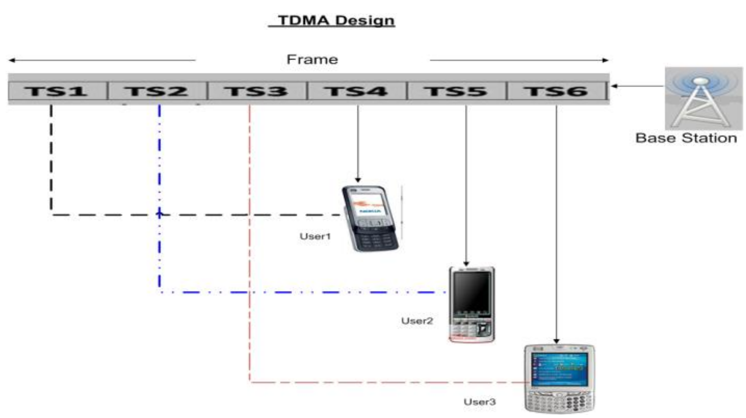


**Figure 6 TDMA design for 3 users**

#1 uses slots 1 and 4, phone #2 uses slots 2 and 5, while phone #3 uses slots 3 and 6

## II. Assumptions for Design & Calculation of TDMA:

**(a)TDMA Hexagonal Cell Structure for number of users/mobiles per channel and traffic covered:**

(1)Population of 850,000.

(2)In our assumption, cluster having 7 cells for TDMA design. Number of channels per cell=395/7=56 channels.

(3)Traffic intensity per user=2/60=0.03 Erlangs

(4)Blocking Probability(GOS)=0.02

(5)In TDMA, each channel has 3 time slots which supports] 3 users. Number of channels per cell=56*3=168. Total carried traffic for 168 channels per cell=153.9 Erlangs

(6)Number of Users that can be supported per cell=153.9/0.03=5130 users

(7)Since there are 33 cells, Maximum carried traffic=Number of cells*traffic intensity per cell

Therefore, Maximum Carried Traffic=33*153.9=5078.7 Erlangs

(8)Total number of users that can be supported by the system=Maximum Carried Traffic/Traffic intensity per user=5078.7/0.03=169290 users

(9)Number of mobiles per channel=Total number of users that can be supported by the system/Traffic intensity per user=169290/395=429 mobiles per channel

**(b)Coverage Area for TDMA**:

Total coverage area=225 (15*15) sq miles

Company can afford only 33 cells

Area covered by each cell=A=225/33=6.82 sq miles

As, $A=2.6*(R^2)$, Therefore, Radius of cell=R=1.618 miles

**(c)Distance and S/I for TDMA:**

The distance between the mobile and the interfering base station is approximately for 1 user is:

$D=\sqrt{((i)^2+(j)^2+ij)}\,\sqrt{3}R$

Where i=1, and j=2, R=1.6445 in the cell design structure for AMPS

**D**$=\sqrt{((1)^2+(2)^2+(1)(2))}\,\sqrt{3}*1.618=7.42$ miles

**Signal-to-Interference Ratio=**$\left(\frac{S}{I}\right)=\frac{\sqrt[4]{3*N}}{6}=\sqrt[4]{21}/6=93.5$ watts=18.66dB

**(d)Digital Modulation, Carrier to Noise Ratio, Noise Density and Receiver Sensitivity**

**(i)Digital Modulation**

Using ∏/4 D-QPSK digital modulation for TDMA design

Let Bit Error Rate=$1*10^{-6}$.

Then Bit Energy to Noise Ratio is given as $E_b/N_o$=11.1dB

**(ii)Carrier to Noise ratio** $\left(\frac{C}{N}\right)=E_b/N_o*(F_b/\text{Bandwidth})$

Where $F_b$ is data rate for TDMA =48.6Kbps

Bandwidth=30KHz

$\left(\frac{C}{N}\right)$**(dB)=**$E_b/N_o$(db)+10*log($F_b$/Bandwidth)=11.1+2.1=13.2dB

(iii)**(Receiver Noise Power)Noise Density** N(dBm)=Noise Figure(F in dB)+ $T_o$(dBK)+K(dBm-$sK^{-1}$)+10*log(B)

As, $T_o$=290K

K=-198.6 dBm-$sK^{-1}$

Channel Bandwidth=30KHz

Let Noise Figure(F)=30dB

**So, Noise Density(N)**=-198.6+10*log(290)+30+10*log(30000)=-99.204dBm

**(iv)Receiver Sensitivity**=$\left(\frac{C}{N}\right)$+N=13.2-99.204=-86dBm

**(e)(Allowable Path loss)Okumura Model for TDMA Design:**
(i)As, R=1.618 miles, so I mile=1.6093 km and Therefore 1.644 miles=2.65 km

Let $\lambda$=0.3529 meters

$\lambda^2$=0.124567 meters

$L_p$(Path Loss)=10log[((4∏)$^2$ * (R)$^2$)/(($\lambda$)$^2$)]
$\mathbf{L_p}$=10log[((4∏)$^2$*(2.65K)$^2$)/0.1111]= 99.32dB
Therefore, **R**=2.65 km

(ii)Let A(f,d)=20dB, Gain Area=9dB, Transmitter Height=200 meters, Receiver Height=3 meters
Therefore, **Gain of Height Transmitter**=20log(200/200)=0 dB
**Gain of Height Receiver**=20log(3/3)=0 dB

**(iii)In TDMA design, Allowable Path is equal to the Okumura Model** defined as:
L(dB)=$L_p$ + A(f,d) - Gain of Height Transmitter - Gain of Height Receiver – Gain Area
**Allowable Path loss=L(dB)**=99.32+20-0-0-9=110.32 dB
**(f)Transmitted Power**
Power transmitted
$P_T$ (dBmW) =$P_R$(dBmW)+L(dB)+Cable loss(dB)- $G_T$ (dB) – $G_R$ (dB)
Let Cable loss=20dB, $G_T$=2dB, $G_R$=0dB
**Power Transmitted=$\mathbf{P_T}$**=86+110.32+20-2-0=44.32dBm

## 6. Conclusion (Which design is better?):

In this research paper from our design depending on Telecom Mobile Company's budget, we learned, observed, and analyzed that the capacity offered by TDMA is more than the capacity offered by AMPS for budget of $20 million for each user channel in the cell site cost additional $1000 . Overall, TDMA design is better than AMPS. However, other observations that we analyzed and learned from both designs are as that:
(1)AMPS are simple to implement and fairly efficient with a small base population, when traffic is constant whereas TDMA cannot.
(2)TDMA is more efficient use of spectrum, compared to AMPS.
(3)The calculated results of Receiver Sensitivity for AMPS and TDMA is. -53.2 dBmW and -86 dBmW, where we analyze AMPS design is more sensitive than TDMA at receiver end
(4)The Noise Density for AMPS and TDMA is -121.205 dBm and -99.204 dBm where TDMA having more noise density as compare to AMPS.
(5)Allowable Path loss for AMPS and TDMA is 27.1 dBW and 110.32 dB.
(6)AMPS can handle video and audio data efficiently than TDMA.
(7)TDMA is not good for Multipath Interference that affects call quality.
(8)In TDMA, dropped calls are possible when users switch in and out of different hexagonal cells.
(9)TDMA design can have higher costs due to greater equipment sophistication as compared to AMPS.
(10)AMPS cannot combine optimization that increases network capacity significantly for non-uniform user distribution whereas TDMA can combine it.
(11)TDMA allows service compatibility with the use of dual-mode handsets than the AMPS.
(12) The designing approach for AMPS and TDMA is same except that in TDMA, each channel is shared by 3 different user in hexagonal cell

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## BIOGRAPHY

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