

## **1.INTRODUCTION**

I will design radio link for mobile telecommunication systems by obtaining optimum conditions for all steps of designing microwave link. Thanks to this report, Çankaya University Electronic and Communication Engineering department academic staff and students will be able to know about my knowledge in telecommunication with radio frequency link design and will be able to evaluate my investigation studies for a senior project.

### **1.1.Background**

In mobile communication systems, to obtain point-to-point transmission without cables microwave links are preferred.

According to topologies, frequency and antenna gain radio link parameters change. Also, fading channels, Free Space Loss (FSL) and modulation types are determined to obtain optimum conditions.

#### **1.1.1.Link Elements**

Transmitting side, propagating side and receiving side are main parts of radio link. Frequency, modulation types and transmitter antenna gains and types are included in transmitting side. Fresnel zone and Free Space Loss calculations, also fading channel calculations are included in propagating side. Receiving side includes receiver antenna gain, cable loss, demodulation of the received signal and evaluation of message signal.

### **1.2.Purposes**

Designing a radio link which has optimum budgets, discussing each elements of link, maximum efficiency for good communication and evaluating the results with reality are purposes of this senior project report.

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### **1.3.Significance**

The result of the senior project, if I have optimum conditions of radio link that will be an example for mobile communication areas. In addition, this report includes all steps of designing radio link; so it will show my investigation studies and knowledge.

### **1.4.Scope**

In this report, topology and some physical features of link and transmission details as fading channels and modulation types are included. Other side, details of antenna as its position like height from ground are excluded.

Project is bounded because I do not have potentialities as making experiments in process. However, I have simulations opportunity.

### **1.5.Sources and Methods**

A GSM company supports this project by providing statistical informations, sharing radio link examples and simulations, documents for the RF plannings. Therefore, I have been able to collect data for primary sources. Also, some books in communication systems area and some articles about the designed radio link projects are included in my secondary sources.

### **1.6.Organization**

The structure of report is progress report which includes the works completed up to now and future works. Then, conclusion part gives evaluation of results of radio link design and a short summary of steps.

### **1.7.Summary**

To design radio link, some elements are important to determine link parameters. These are transmitting power, antenna gains, Free Space Loss (FSL), modulation types and receiving power. They are placed in body part of report.

## **2.WORKS COMPLETED**

Up to now, being able to choose distance and frequency all investigations are completed. Elements of Radio Link are separated by transmitting side, propagating side and receiver side. The, in terms of these elements and Free Space Loss calculation I have decided my Link parameters such as distance, frequency and antenna gain.

### **2.1. Choosing Topology**

Radio Links are designed in highlands, marine lands and in cities which have some fields that is difficult to design fiber access systems. Therefore, antennas are places at the hill of mountains or provide directly connection and refuse the reflections because of obstacles. (Proakis et al., 2002, p.675). According to this information, I have chosen the distance as 15 km for a rural area.

### **2.2.Determination of Frequency**

Frequency is carrier of message signal and it is determined according to bandwidth of message signal and distance, which is inversely proportional with frequency. Therefore, frequency has been determined as 8.5 GHz by my project supervisor from the company.(GSM operator company).

### **2.3.Antenna Gain**

Antennas are produced all over the world according to some standards and this table which has been given by the supervisor company is below.

**Table 1**  
**Microwave Radio Links Antenna Gain**  
**in dB**

Size [m]	Frequency [GHz]										
	6	7/8	11	13	15	18	23	26	28	32	38
0.2							30.8	32.9	33.8	35.2	37.3
							31.8	33.8	34.6	35.4	37.5
							32.8	34.4	34.8	35.6	37.7
0.3					31.7	33.9	35.6	36.4	37.5	?	40.3
					32.1	34.4	36.2	37.3	38.0	?	40.4
					32.8	35.2	36.6	37.8	38.5	?	40.5
0.6		31.0	34.9	35.8	36.2	38.6	39.6	40.6	41.7	?	44.0
		32.0	35.2	36.0	36.6	39.2	40.0	41.5	42.4	?	44.3
		32.7	35.4	36.2	36.8	39.6	40.8	42.2	42.8	?	44.3
1.2	35.0	36.4	39.8	41.5	42.6	44.3	45.5	46.7	47.5	48.1	
	35.8	37.0	40.3	41.8	42.7	44.6	46.0	47.1	47.9	48.3	
	36.5	37.9	40.7	42.5	43.2	44.9	46.5	47.4	48.2	48.5	
1.8	38.5	40.1	43.3	45.1	46.1	48.0	49.1				
	39.3	41.0	43.8	45.3	46.4	48.5	49.5				
	40.0	41.7	44.2	45.6	46.6	48.9	50.0				

SOURCE: Supervisor GSM Company

Antenna gain is important for the transmission of signal which have high SNR (Signal to Noise Ratio) value. Increasing signal power is not mostly preferred because it is acceptable as the last thing to obtain a good communication system. As a result, antenna gain is an important parameter to increase transmitting power.

#### 2.4.Free Space Loss (FSL)

Because of the free space attenuation, signal loses its most of power when it oscillates in air. FSL represents loss in atmosphere without obstacles.

It is calculated according to this formula:

$$FSL = 36.6 + 20 \times \log (F) + 20 \times \log (D)$$

where

D = Distance in miles

F = Frequency in MHz

(Jimenez, 1999, p.6)

However, I use km for distance and GHz for frequency; so formula returns to ,

$$FSL = 92.45 + 20 \times \log (F) + 20 \times \log (D)$$

According to radio link parameters;

$$FSL = 92.45 + 20 \times \log (8.5) + 20 \times \log (15)$$

It is calculated as approximately 135 dB.

### **3.WORKS TO BE COMPLETED**

#### **3.1.Choosing Bandwidthes**

According to message signal bit rate, bandwidth is determined. Then, bandwidth is used when Signal to Noise Ratio (SNR) is calculated. SNR formula is below.

$$SNR = (E_b \times R_b) / (N_0 \times B_w) \quad (\text{in dB})$$

$E_b$ : Signal Power (in Watt )

$R_b$ : Bit Rate (in 1/sec)

$N_0$ : Noise Power (in Watt)

$B_w$ : Bandwidth (in 1/sec)

(Eyyuboğlu et al., 2012, p.1)

#### **3.2.QAM with Different M-Levels**

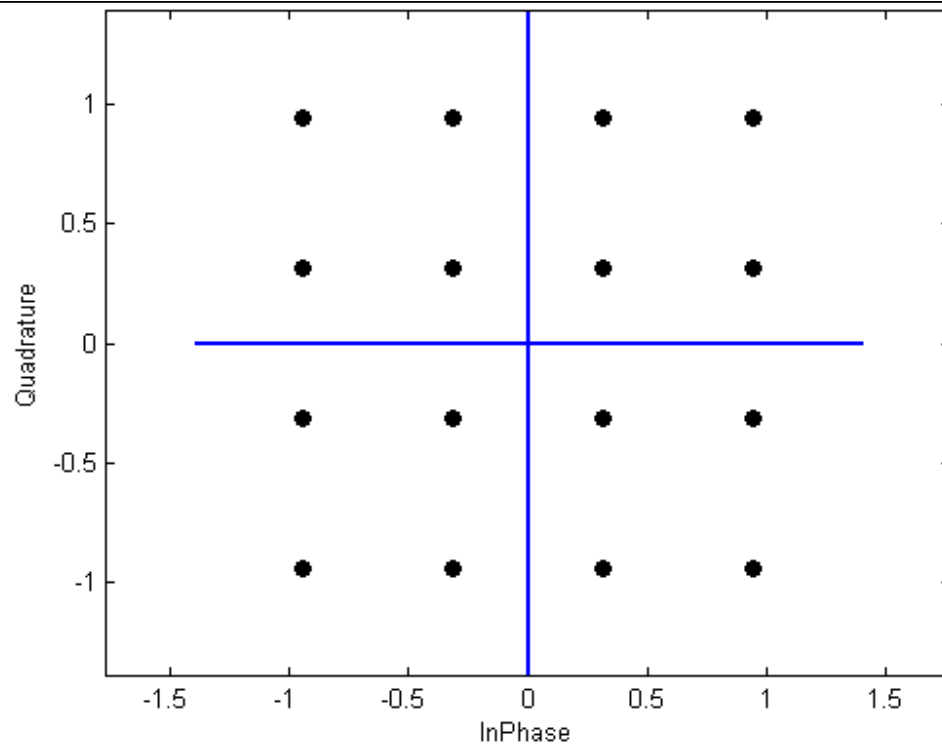
Quadrature Amplitude Modulation (QAM) is both analog and digital modulation technique. It is combination of Amplitude Shift Keying (ASK) and Phase Shifting Keying (PSK).

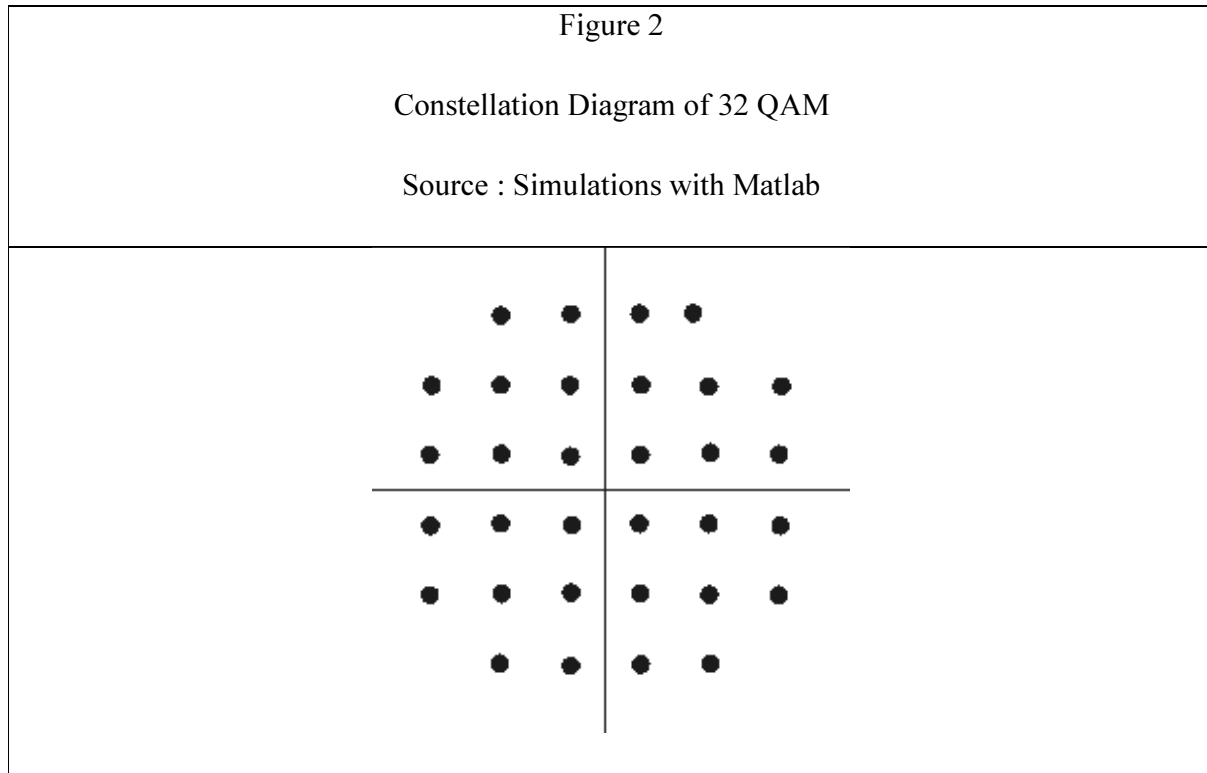
To carry message signal, I will use Mary Level 16 and Mary Level 32 QAM in transmitting side. Their constellation diagram is placed in Figure 1 and Figure 2.

Figure 1

Constellation Diagram of 16 QAM

Source: Simulations with Matlab

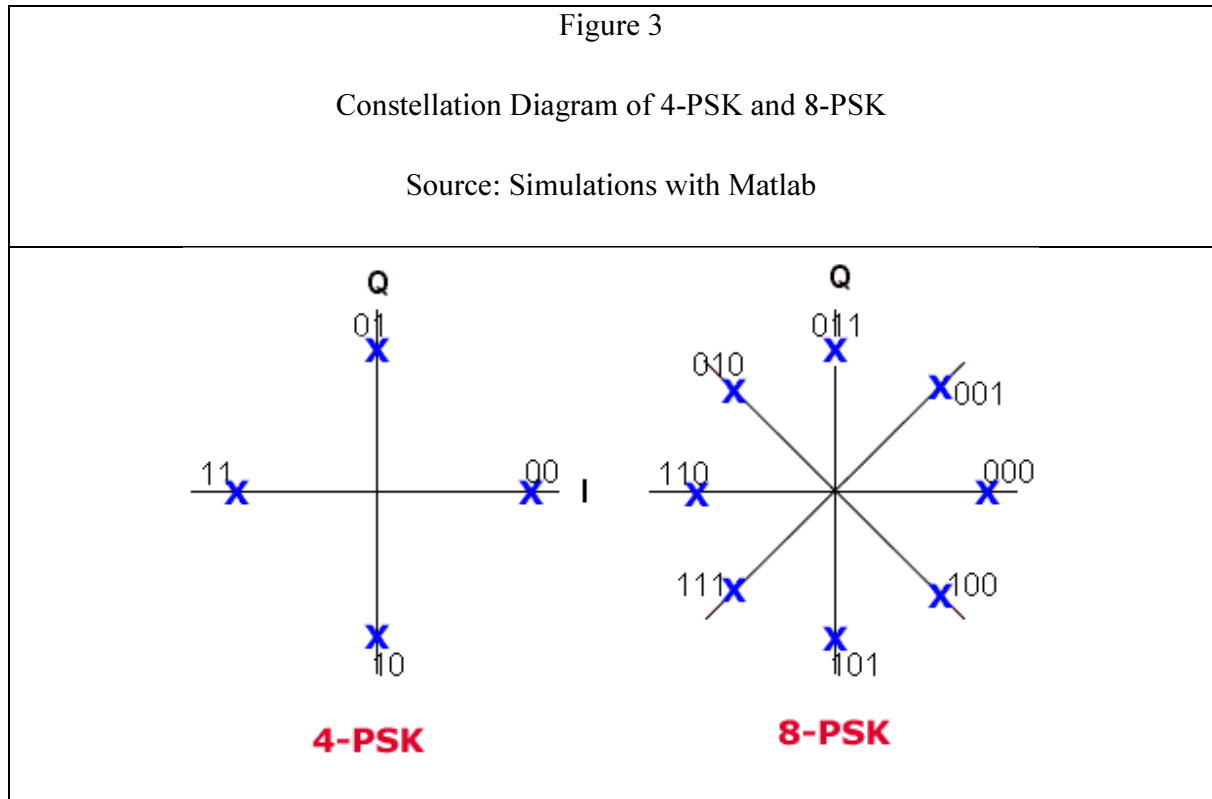




### 3.3.PSK with Different M-Levels

Phase Shifting Keying (PSK) is a digital modulation technique. Message signal conveys according to phase of reference signal which means carrier signal. Each phase encodes a group of bits.

I will use in transmitting side in order to carry message signal 4 Mary Level and 8 Mary Level PSK.



#### 4.CONCLUSION

In conclusion, I have been designing a radio link for mobile communication systems for areas without fiber or other cables access. This link is grouped by a transmitting side, propagating side and receiving side to obtain efficient and useful communication channel. My investigations and real life examples received from project supervisor company have helped when I decided my radio link parameter and calculations. In future works, different modulation techniques will be used and the most efficient one will be chosen as a modulation technique for transmitting side.



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## REFERENCES

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Radyo link tasarımı. Ankara : Çankaya Üniversitesi.
- Jimenez, J.F. (1999, 30 March).** Fundamentals of radio link engineering. Retrieved (n.d), from  
<http://pathengineering.com> .
- Proakis, J.G.& Salehi, M. (2002).** *Communication Systems Engineering.* New Jersey : Prentice-Hall Inc.

## APPENDIX A

### Microwave Radio Links Antenna Gain Table From Supervisor GSM Company

Microwave Radio Links Antenna Gain Table According to Operating Frequency and Diameter of Antenna

Size [m]	Frequency [GHz]										
	6	7/8	11	13	15	18	23	26	28	32	38
0.2							30.8	32.9	33.8	35.2	37.3
							31.8	33.8	34.6	35.4	37.5
							32.8	34.4	34.8	35.6	37.7
0.3					31.7	33.9	35.6	36.4	37.5	?	40.3
					32.1	34.4	36.2	37.3	38.0	?	40.4
					32.8	35.2	36.6	37.8	38.5	?	40.5
0.6		31.0	34.9	35.8	36.2	38.6	39.6	40.6	41.7	?	44.0
		32.0	35.2	36.0	36.6	39.2	40.0	41.5	42.4	?	44.3
		32.7	35.4	36.2	36.8	39.6	40.8	42.2	42.8	?	44.3
1.2	35.0	36.4	39.8	41.5	42.6	44.3	45.5	46.7	47.5	48.1	
	35.8	37.0	40.3	41.8	42.7	44.6	46.0	47.1	47.9	48.3	
	36.5	37.9	40.7	42.5	43.2	44.9	46.5	47.4	48.2	48.5	
1.8	38.5	40.1	43.3	45.1	46.1	48.0	49.1				
	39.3	41.0	43.8	45.3	46.4	48.5	49.5				
	40.0	41.7	44.2	45.6	46.6	48.9	50.0				

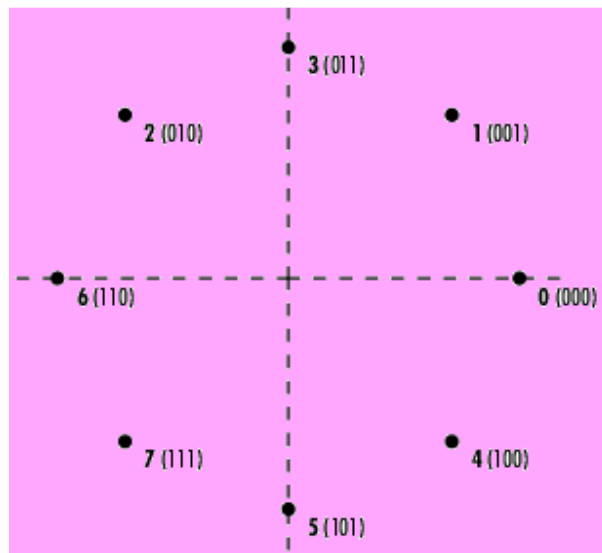
## APPENDIX B

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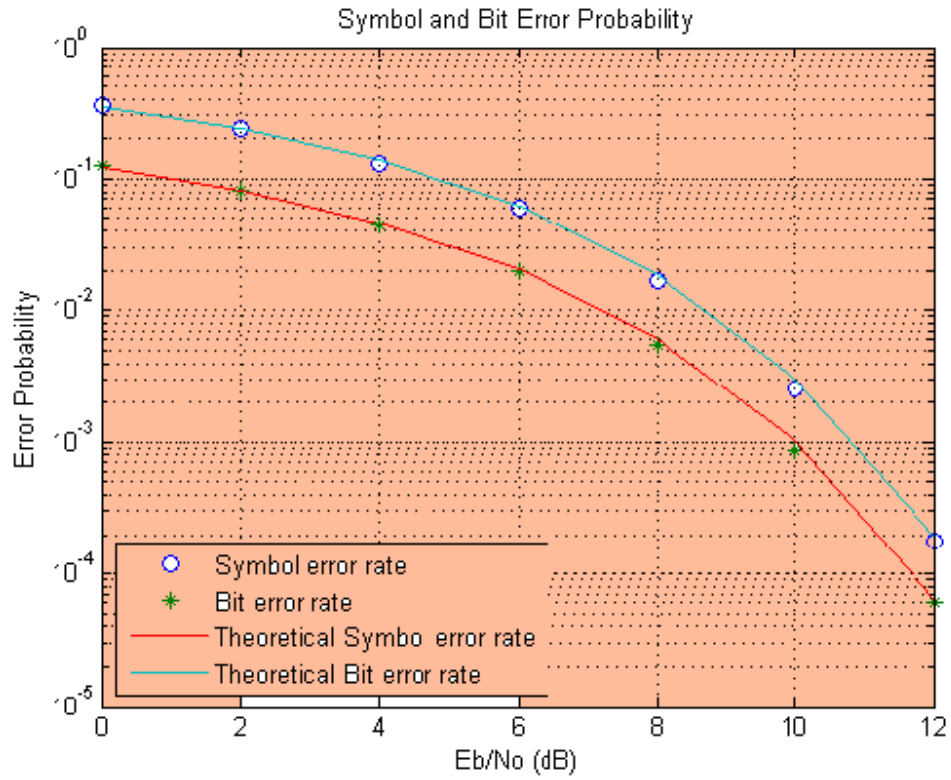
### 8-PSK Modulator Input and Output Table, BER Graph From MATLAB

Modulator Output	Modulator Input
$\exp(0)$	000
$\exp(j\pi/4)$	001
$\exp(j\pi/2) = \exp(j2\pi/4)$	011
$\exp(j3\pi/4)$	010
$\exp(j\pi) = \exp(j4\pi/4)$	110
$\exp(j5\pi/4)$	111
$\exp(j3\pi/2) = \exp(j6\pi/4)$	101
$\exp(j7\pi/4)$	100

According to this table, Constellation Diagram of 8-PSK



This figure shows Bit Error Probability (BER) values, according to SNR ( $E_b/N_0$ ) and Errors Probability values.



## APPENDIX C

### Link Budget Example of A Real Link From Supervisor GSM Company

Real Life Example of A Link table shows link budgets.

<b>Link</b>			
Link ID		SITEC-SITED	
Name		KIRIKKALE	
Length (km)		0.72	
Main Polarisation		Vertical	
<b>Linkend</b>	<b>End A</b>		<b>End B</b>
Main Centre Frequency (GHz)	37.359000		38.619000
Main Bandwidth (MHz)	14.00000		14.00000
Main Frequency Designation	Low		High
Main Antenna Type	NEC_38_GHz/0.6m		NEC_38_GHz/0.6m
Main Antenna Size (m)	0.60		0.60
Main Antenna Height (m)	25.00		25.00
Main Antenna Ground Height (m)	718.00		749.00
Main Antenna Direction (°)	74.34		254.34
Main Antenna Gain (dB)	32.0		32.0
Main Tx Power (dBm)	18.00		18.00
Main Tx Attenuator (dB)	13.00		13.00
Main Operating Mode	Single		Single
<b>Performance</b>	<b>End A</b>		<b>End B</b>
Freespace Loss (dB)		121.3248	
Rx Level (dBm)	-26.4178		-26.1237
Dispersive Fade Margin (dB)	64.6534		64.6534
<b>Flag Data</b>			
Supplier		Link : NEC	
Antenna A Position		Link : P1	
Antenna B Position		Link : Tower	

This part is  
optional

## GLOSSARY OF TERMS

**Carrier Signal** – This signal is mostly high frequency signal and modulated with an input signal in communication systems.

**Fading** – In wireless and mobile communication systems, signal is attenuated by the propagation media and this affect is called fading.

**Message Signal** – This signal is input for the transmitting side and output for the receiving side. What is transmitted int the system refers to message signal.

**Microwave** – Microwaves are waves their wavelengthes ranging from one meter to one milimeter. Signals have frequency range 300 MHz to 300 GHz are called microwaves.

**Link Budget** – Link budget is a calculation of all gains, lossess for a radio link. As a result, it gives information about the receiver power and link reliability.

**Propagation** – Radio signals are transmitted from the transmitter and up to arrive the receiver go in the atmosphere and this event is called propagation.

**Radio Link** - Microwave links which are used in mobile telecommunications and provide point to point communication. It is called Radio Link because of operating at Radio Frequencies.

**Trasnmission** – The process of sending and propagating analog and digital signal in a transmission medium like coaxial cable, fiber and wireless.