

Data Communications and Networking Fourth Edition

Chapter 5 Analog Transmission

Introduction

- For digital transmission low-pass channel is
• For digital transmission low-pass channel is
needed. needed. **Analog 1 Introduction**

• For digital transmission low-pass channel is

• Analog transmission is the only choice for band-

pass channel. **Example 13**
For digital transmission low-
needed.
Analog transmission is the only
pass channel.
Converting digital data to a b
-
- Converting digital data to a band-pass analog For digital transmission low-pass channel is

needed.

Fanalog transmission is the only choice for band-

pass channel.

For Converting digital data to a band-pass analog

signal is traditionally known as digital-to-analog conversion. • Analog transmission is the only choice for band-

pass channel.

• Converting digital data to a band-pass analog

signal is traditionally known as digital-to-analog

converting a low-pass analog signal to a band-

pass a
- Analog transmission is the only choice for band-
pass channel.
Converting digital data to a band-pass analog
signal is traditionally known as digital-to-analog
conversion.
Converting a low-pass analog signal to a band-
pas pass channel.
Converting digital data to a band-
signal is traditionally known as digit
conversion.
Converting a low-pass analog signa
pass analog signal is traditionally ca
to-analog transmission.

Digital to Analog Conversion

- Digital to Analog Conversion
- Digital-to-analog conversion is the process of
changing one of the characteristics of an analog
cignal based on the information in digital data **Example 15 Digital to Analog Conversion
Digital-to-analog conversion is the process of
changing one of the characteristics of an analog
signal based on the information in digital data.** Digital to Analog Conversion
Digital-to-analog conversion is the process of
changing one of the characteristics of an analog
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Digital data needs to be carried on an analog Digital to Analog Conversion

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Digital data needs to be carried on an analo • Digital-to-analog conversion is the process of
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• Digital data needs to be carried on an analog
signal.
• A carrier signal the process of
cics of an analog
in digital data.
d on an analog
) performs the
gital data in an
- signal.
- Digital-to-analog conversion is the process of
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Digital data needs to be carried on an analog
signal.
A carrier signal (freq changing one of the characteristion
signal based on the information in
Digital data needs to be carried
signal.
A carrier signal (frequency f_c)
function of transporting the digi
analog waveform.
The analog carrier signal • Digital data needs to be carried on an analog
signal.
• A carrier signal (frequency f_c) performs the
function of transporting the digital data in an
analog waveform.
• The analog carrier signal is manipulated to
uniqu Digital data needs to be carried on an analog
signal.
A carrier signal (frequency f_c) performs the
function of transporting the digital data in an
analog waveform.
The analog carrier signal is manipulated to
uniquely ide
-

Figure 5.1 Digital-to-analog conversion

Digital to Analog Conversion (Conti…)

- A sine wave (analog Conversion (Conti...)
A sine wave (analog signal) is defined by three
characteristics: amplitude, frequency and phase. Digital to Analog Conversion (Conti...)
A sine wave (analog signal) is defined by three
characteristics: amplitude, frequency and phase.
By changing any of these characteristics can By changing any of these characteristics can
create a different version (Conti...)
By changing any of these characteristics can
create a different version of that wave. Digital to Analog Conversion (Conti...)
A sine wave (analog signal) is defined by three
characteristics: amplitude, frequency and phase.
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create a different version of that wave. A sine wave (analog signal) is defined by three

characteristics: amplitude, frequency and phase.

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Digital to analog conversion mechani
- A sine wave (analog signal) is defined by three

characteristics: amplitude, frequency and phase.

By changing any of these characteristics can

rreate a different version of that wave.

Digital to analog conversion mechan France Constants Completive Characteristics: amplitude, frequency and phase Sy changing any of these characteristics carreate a different version of that wave.

Digital to analog conversion mechanisms:

The Amplitude Shift By changing any of these characteristics can
preate a different version of that wave.
Digital to analog conversion mechanisms:
• Amplitude Shift Keying (ASK)
• Frequency Shift Keying (FSK)
• Phase Shift Keying (PSK)
• Quad
- Digital to analog conversion mechanisms:
	-
	-
	-
	-

Figure 5.2 Types of digital-to-analog conversion

Aspects of Digital to Analog Conversion Aspects of Digital to Analog Conversion
• Data Element Versus Signal Element
• Data Rate Versus Signal Rate **Example 25 Aspects of Digital to Analog Conversion**

• Data Element Versus Signal Element

• Data Rate Versus Signal Rate

• Bandwidth

-
-
- **Bandwidth**
- Carrier Signal
- Data Element Versus Signal Element

Data Rate Versus Signal Rate

Bandwidth

Farrier Signal

 In analog transmission, the sender generate a

high frequency signal acts as base for the

message (information) signal, known ta Element versus Signal Element
ta Rate Versus Signal Rate
ndwidth
rrier Signal
In analog transmission, the sender generate a
high frequency signal acts as base for the
message (information) signal, known as carrier
signa ta Rate Versus Signal Rate
ndwidth
rrier Signal
In analog transmission, the sender generate a
high frequency signal acts as base for the
message (information) signal, known as carrier
signal or carrier frequency. Reflexive versus signal Kate

In analog transmission, the sender generation

In analog transmission, the sender generation

high frequency signal acts as base for

message (information) signal, known as c

signal or carrie

Aspects of Digital to Analog Conversion (Conti…) Aspects of Digital to Analog Co (Conti...)
• Carrier Signal (Conti...)
• Digital data changes the carrier si

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- Aspects of Digital to Analog Conversion

(Conti...)

Carrier Signal (Conti...)

Digital data changes the carrier signal by

modifying one or more of its characteristics

(amplitude frequency or phase) __ Aspects of Digital to Analog Conversion
(Conti...)
rrier Signal (Conti...)
Digital data changes the carrier signal by
modifying one or more of its characteristics
(amplitude, frequency, or phase). __ Aspects of Digital to Analog Conversion

(Conti...)

rrier Signal (Conti...)

Digital data changes the carrier signal by

modifying one or more of its characteristics

(amplitude, frequency, or phase).

Such kind of mod (Conti...)

rrier Signal (Conti...)

Digital data changes the cari

modifying one or more of its

(amplitude, frequency, or phase).

Such kind of modification is called

(shift keying).

The receiver is tuned to the fre -arrier signal (Conti...)

• Digital data changes the carrier signal by

modifying one or more of its characteristics

(amplitude, frequency, or phase).

• Such kind of modification is called as modulation

(shift keying). Digital data changes the carrier signal by
modifying one or more of its characteristics
(amplitude, frequency, or phase).
Such kind of modification is called as modulation
(shift keying).
The receiver is tuned to the frequ
	- Such kind of modification is called as modulation
	-

Aspects of Digital to Analog Conversion (Conti…)

Aspects of Digital to Analog Conversion

(Conti...)

Example 5.1: An analog signal carries 4 bits per

signal element. If 1000 signal elements are sent **Example 5.1:** Aspects of Digital to Analog Conversion

(Conti...)

Example 5.1: An analog signal carries 4 bits per

signal element. If 1000 signal elements are sent

per second, find the bit rate. Aspects of Digital to Analog Conversi

(Conti...)

Example 5.1: An analog signal carries 4 bits pe

signal element. If 1000 signal elements are sen

per second, find the bit rate.

Solution:

In this case, $r = 4$, $S = 1000$, and N is unknown. We can find the value of N from:

$$
S = N \times \frac{1}{r}
$$
 or
$$
N = S \times r = 1000 \times 4 = 4000
$$
bps

Aspects of Digital to Analog Conversion (Conti…)

Aspects of Digital to Analog Conversion

(Conti...)

Example 5.2: An analog signal has a bit rate of

8000 bps and a baud rate of 1000 baud. How Aspects of Digital to Analog Conversion

(Conti...)

Example 5.2: An analog signal has a bit rate of

8000 bps and a baud rate of 1000 baud. How

many data elements are carried by each signal

alement? How many signal elem Aspects of Digital to Analog Conversion

(Conti...)

Example 5.2: An analog signal has a bit rate of

8000 bps and a baud rate of 1000 baud. How

many data elements are carried by each signal

element? How many signal elem **Example 5.2:** An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?
Solution:

Solution:

In this example, $S = 1000$, $N = 8000$, and r and L are unknown. We find first the value of r and then the value of L.

$$
S = N \times \frac{1}{r} \longrightarrow r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}
$$

$$
r = \log_2 L \longrightarrow L = 2^r = 2^8 = 256
$$

Amplitude Shift Keying (ASK)

- In Amplitude Shift Keying (ASK)

In ASK, the amplitude of the carrier signal is

varied to create signal elements, while both

frequency and phase remain constant Amplitude Shift Keying (ASK)
In ASK, the amplitude of the carrier signal is
varied to create signal elements, while both
frequency and phase remain constant. Amplitude Shift Keying (ASK)
In ASK, the amplitude of the carrier signal is
varied to create signal elements, while both
frequency and phase remain constant.
ASK can have several levels (kinds) of signal **AMPLA CONTROVIDER AMPLA CONTROVIDED**

• In ASK, the amplitude of the carrier signal is

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frequency and phase remain constant.

• ASK can have several levels (kinds) of signal
 ■ In ASK, the amplitude of the carrier signal is
varied to create signal elements, while both
frequency and phase remain constant.
■ ASK can have several levels (kinds) of signal
elements, each with different amplitude.
■
- elements, each with different amplitude.
- In ASK, the amplitude of the carrier signal is
varied to create signal elements, while both
frequency and phase remain constant.
ASK can have several levels (kinds) of signal
elements, each with different amplitude.
Normal (OOK).

ASK (Conti…)

- The peak amplitude of one signal level is 0 while
• The peak amplitude of one signal level is 0 while
other is same as amplitude of the carrier signal. ASK (Conti...)
The peak amplitude of one signal level is 0 while
other is same as amplitude of the carrier signal.
The bandwidth B of ASK is proportional to the
- The peak amplitude of one signal level is 0 while

The peak amplitude of one signal level is 0 while

The bandwidth B of ASK is proportional to the

signal rate S: **EXECUTE:**
The peak amplitude of one signal lever
other is same as amplitude of the carr
The bandwidth B of ASK is proportion
signal rate S:
 $B = (1+d)S$

 $B = (1+d)S$

• The peak amplitude of one signal level is 0 while

other is same as amplitude of the carrier signal.

• The bandwidth B of ASK is proportional to the

signal rate S:
 $B = (1+d)S$

• "d" is due to modulation and filtering, other is same as amplitude or the carrier s
The bandwidth B of ASK is proportional
signal rate S:
 $B = (1+d)S$
"d" is due to modulation and filterin
between 0 and 1.

Figure 5.3 Binary amplitude shift keying

Implementation of ASK

- The line encoding will determine the values of
The line encoding will determine the values of
the analog waveform to reflect the digital data Implementation of ASK
The line encoding will determine the values of
the analog waveform to reflect the digital data
being carried. Implementation of ASK
The line encoding will determin
the analog waveform to reflect
being carried.
If the digital data is presented Implementation of ASK

• The line encoding will determine the values of

the analog waveform to reflect the digital data

being carried.

• If the digital data is presented as Unipolar NRZ

digital signal with a high volta
- Implementation of ASK
The line encoding will determine the values of
the analog waveform to reflect the digital data
being carried.
If the digital data is presented as Unipolar NRZ
digital signal with a high voltage of 1V voltage of 0V, the implementation can achieved The line encoding will determine the values of
the analog waveform to reflect the digital data
being carried.
If the digital data is presented as Unipolar NRZ
digital signal with a high voltage of 1V and low
voltage of 0V, The line encoding will determine the values of
the analog waveform to reflect the digital data
being carried.
If the digital data is presented as Unipolar NRZ
digital signal with a high voltage of 1V and low
voltage of 0V, The analog waveform to reflect the digital data

• If the digital data is presented as Unipolar NRZ

digital signal with a high voltage of 1V and low

voltage of 0V, the implementation can achieved

by multiplying the NRZ amalog material.

If the digital data is presented as Unipolar NRZ

digital signal with a high voltage of 1V and low

voltage of 0V, the implementation can achieved

by multiplying the NRZ digital signal by the

carrier si being camboat of the digital data is presented as Unipolar NRZ
digital signal with a high voltage of 1V and low
voltage of 0V, the implementation can achieved
by multiplying the NRZ digital signal by the
carrier signal com If the algreat data to present
digital signal with a high vo
voltage of 0V, the implemer
by multiplying the NRZ di
carrier signal coming from ar
When the amplitude of the
amplitude of the carrier s
when it is 0, the amplit
-

Implementation of ASK (Conti…)

Figure 5.4 Implementation of binary ASK

ASK (Conti…)

**Example 5.3: We have an available bandwidth of
Example 5.3: We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What 100 kHz** ASK (Conti...)
100 kHz which spans from 200 to 300 kHz. What
100 kHz which spans from 200 to 300 kHz. What
are the carrier frequency and the bit rate if we **Example 5.3:** We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with $d = 1$? **Example 5.3:** We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
are the carrier frequency and the bit rate if we
modulated our data by using ASK with d = 1?
Solution: Example 5.3: We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
are the carrier frequency and the bit rate if we
modulated our data by using ASK with $d = 1$?
Solution:
The middle of the bandwi Example 5.3: We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
are the carrier frequency and the bit rate if we
modulated our data by using ASK with $d = 1$?
Solution:
The middle of the bandwi

Solution:

Example 3.3. We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
are the carrier frequency and the bit rate if we
modulated our data by using ASK with d = 1?
Solution:
The middle of the bandwid Too KHz Wilch Spans from 200 to 300 KHz. What
are the carrier frequency and the bit rate if we
modulated our data by using ASK with d = 1?
Solution:
The middle of the bandwidth is located at 250 kHz.
This means that our c

$$
B = (1 + d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \longrightarrow N = 50 \text{ kbps}
$$

ASK (Conti…)

Example 5.4: In data communications, we
Example 5.4: In data communications, we
normally use-full-duplex-links-with-communication
in both directions, We need to divide the **normally depth (Conti**...)
Assumple 5.4: In data communications, we
normally use full-duplex links with communication
in both directions. We need to divide the **in directions.**
 Example 5.4: In data communications, we

normally use full-duplex links with communication

in both directions. We need to divide the

bandwidth into two with two carrier frequencies, **Example 5.4:** In data communications, we
hormally use full-duplex links with communication
in both directions. We need to divide the
bandwidth into two with two carrier frequencies,
as shown in Figure 5.5. The figure show **Example 5.4:** In data communications, we
normally use full-duplex links with communication
in both directions. We need to divide the
bandwidth into two with two carrier frequencies,
as shown in Figure 5.5. The figure sho positions of two carrier frequencies and the **Example 5.4:** In data communications, we
normally use full-duplex links with communication
in both directions. We need to divide the
bandwidth into two with two carrier frequencies,
as shown in Figure 5.5. The figure show Example 5.4: In data communications, we
normally use-full-duplex-links-with-communication
in both directions. We need to divide the
bandwidth into two with two carrier frequencies,
as shown in Figure 5.5. The figure shows normally use full-duplex links with communication
in both directions. We need to divide the
bandwidth into two with two carrier frequencies,
as shown in Figure 5.5. The figure shows the
positions of two carrier frequencies

Figure 5.5 Bandwidth of full-duplex ASK used in Example 5.4

Frequency Shift Keying (FSK)

- In Frequency Shift Keying (FSK)
In FSK, the frequency of the carrier signal is
varied to represent the data. Frequency Shift Keying (FSK)
In FSK, the frequency of the carrier signal is
varied to represent the data.
Both peak amplitude and phase remain constant Frequency Shift Keying (FSK)

For the Frequency of the carrier signal is

For the peak amplitude and phase remain constant

for all signal elements. Frequency Shift Keying (FSK)
In FSK, the frequency of the carrier
varied to represent the data.
Both peak amplitude and phase remain
for all signal elements.
One wav about binary FSK (BFSK) is to ■ In FSK, the frequency of the c
varied to represent the data.
■ Both peak amplitude and phase r
for all signal elements.
■ One way about binary FSK (BFSK
carrier frequencies.
■ First carrier frequency is used
-
- One way about binary FSK (BFSK) is to user two
- varied to represent the data.

 Both peak amplitude and phase remain constant

for all signal elements.

 One way about binary FSK (BFSK) is to user two

carrier frequencies.

 First carrier frequency is used if the dat Both peak amplitude and phase remain constant
for all signal elements.
One way about binary FSK (BFSK) is to user two
carrier frequencies.
First carrier frequency is used if the data
element is 0, while second is used if t Both peak amplitude and phase remat
for all signal elements.
One way about binary FSK (BFSK) is
carrier frequencies.
First carrier frequency is used if
element is 0, while second is used
element is 1.

Figure 5.6 Binary frequency shift keying

Frequency Shift Keying (FSK)

- **Figure 5.6 shows that the middle of one**
Figure 5.6 shows that the middle of one
bandwidth is f_1 while the middle of other is f_2 . **Example 18 Frequency Shift Keying (FSK)**
Figure 5.6 shows that the middle of one
bandwidth is f₁ while the middle of other is f₂.
Both f₁ and f₂ are 2.1 apart from the midpoint . **Example 1.1** Frequency Shift Keying

Figure 5.6 shows that the

bandwidth is f_1 while the middle

Both f_1 and f_2 are 2 Δf apart frequenties two bands. requency Shift Keying (FSK)
5.6 shows that the middle
th is f_1 while the middle of othe
and f_2 are 2 Δf apart from the
in the two bands. are 2 Δf apart from the middle of one
while the middle of other is f_2 .
are 2 Δf apart from the midpoint
vo bands. **Example 18 Frequency Shift Keying (FSK)**
Figure 5.6 shows that the middle of
bandwidth is f_1 while the middle of other is to
Both f_1 and f_2 are 2 Δf apart from the mid
between the two bands.
- bandwidth is f_1 while the middle of other is f_2

 Both f_1 and f_2 are 2 Δf apart from the midp

between the two bands.

 The difference between the two frequencie

2 Δf .

 Bandwidth of FSK is:
 $B = (1+d) \times$
- The difference between the two frequencies is $2\Delta f$.
-

$$
B = (1+d) \times S + 2\Delta f
$$

FSK (Conti…)

Example 5.5: We have an available bandwidth of
Example 5.5: We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What **100 kHz** FSK (Conti...)
100 kHz which spans from 200 to 300 kHz. What
100 kHz which spans from 200 to 300 kHz. What
should be the carrier frequency and the bit rate if **FORE ASSET AND REF AND REF Should be the carrier frequency and the bit rate if we modulated our data by using FSK with** $d = 1$ **? Example 5.5:** We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
should be the carrier frequency and the bit rate if
we modulated our data by using FSK with d = 1?
Solution: Example 5.5; We have an available bandwidth of
100 kHz which spans from 200 to 300 kHz. What
should be the carrier frequency and the bit rate if
we modulated our data by using FSK with $d = 1$?
Solution:
This problem is si **Example 5.5:** We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with $d = 1$?
Solution:
This problem is

Solution:

Example 5.5. We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with $d = 1$?
Solution:
This problem is si should be the carrier frequend
we modulated our data by usin
Solution:
This problem is similar to Exar
modulating by using FSK. Th
band is at 250 kHz. We choos
this means:
 $\frac{1}{B = (1+d) \times S + 2\Delta f} = 100 \longrightarrow 2S = 50 \text{ kH}$

FSK (Conti…)

- THE TRIM (Conti...)
Two ways of implementation of BFSK: non-
coherent and coherent. ERRIT (Conti...)
Two ways of implementation of BFS
coherent and coherent.
Th non-coherent BFSK, there m
- FSK (Conti...)

I Two ways of implementation of BFSK: non-

coherent and coherent.

In non-coherent BFSK, there may be

discontinuity in the phase when one signal

clement ends and the next begins FSK (Conti...)
Two ways of implementation of BFSK: non-
coherent and coherent.
In non-coherent BFSK, there may be
discontinuity in the phase when one signal
element ends and the next begins. element ends and the next begins. ■ Two ways of implementation of BFSK: non-

coherent and coherent.

■ In non-coherent BFSK, there may be

discontinuity in the phase when one signal

element ends and the next begins.

■ In coherent BFSK, the phase contin Two ways of implementation of BFSK: non-
coherent and coherent.
In non-coherent BFSK, there may be
discontinuity in the phase when one signal
element ends and the next begins.
In coherent BFSK, the phase continues through

-

Figure 5.7 Implementation of BFSK

Multi-Level FSK

- Similarly to ASK, FSK
Similarly to ASK, FSK can use multiple bits per
signal element. Multi-Level FSK
Similarly to ASK, FSK can use r
signal element.
For example four different frequ
- For example four different frequencies f_1 , f_2 , f_3 , f_4 and are used to send 2 bits at a time. oits per per
, f₃, \overline{a} f_4 and are used to send 2 bits at a time. <u>Multi-Level FSK</u>
milarly to ASK, FSK can use multiple bits per
gnal element.
or example four different frequencies f₁, f₂, f₃,
and are used to send 2 bits at a time.
milarly to send 3 bits at a time, eight different Similarly to ASK, FSK can use multiple bits signal element.
For example four different frequencies f_1 , f_2 , f_4 and are used to send 2 bits at a time.
Similarly to send 3 bits at a time, eight different frequencies ■ Similarly to ASK, FSK can use multiple bits per
signal element.

■ For example four different frequencies f_1 , f_2 , f_3 ,
 f_4 and are used to send 2 bits at a time.

■ Similarly to send 3 bits at a time, eight • For example four different frequencies f_1 , f_2 , f_3 , f_4 and are used to send 2 bits at a time.

• Similarly to send 3 bits at a time, eight different frequencies can be used.

• The frequencies need to be 2∆
- Similarly to send 3 bits at a time, eight different For example four different frequencies f_1 , f_2 , f_3 , f_4 and are used to send 2 bits at a time.

■ Similarly to send 3 bits at a time, eight different frequencies can be used.

■ The frequencies need to be 2∆f
-
-
-

 $B = (1+d) \times S + (L-1)/2\Delta f = L \times S$

Multi-Level FSK (Conti…)

Example 5.6: We need to send data 3 bits at a
Example 5.6: We need to send data 3 bits at a
time at a bit rate of 3 Mbps. The carrier frequency Multi-Level FSK (Conti...)

Example 5.6: We need to send data 3 bits at a

time at a bit rate of 3 Mbps. The carrier frequency

is 10 MHz. Calculate the number of levels **is 10** Multi-Level FSK (Conti...)
Example 5.6: We need to send data 3 bits at a
time at a bit rate of 3 Mbps. The carrier frequency
is 10 MHz. Calculate the number of levels
(different frequencies), the baud rate, and the **Example 5.6:** We need to send data 3 bits at a
time at a bit rate of 3 Mbps. The carrier frequency
is 10 MHz. Calculate the number of levels
(different frequencies), the baud rate, and the
bandwidth. bandwidth. Example 5.6: We need to send data 3 bits at a
time at a bit rate of 3 Mbps. The carrier frequency
is 10 MHz. Calculate the number of levels
(different frequencies), the baud rate, and the
bandwidth.
Solution:
We can have Example 5.6. we need to send data 5 bits at a
time at a bit rate of 3 Mbps. The carrier frequency
is 10 MHz. Calculate the number of levels
(different frequencies), the baud rate, and the
bandwidth.
Solution:
We can have

Solution:

fine at a bit rate of 3 Mbps. The carrier frequencies
is 10 MHz. Calculate the number of levels
(different frequencies), the baud rate, and the
bandwidth.
Solution:
We can have L = 2^3 = 8. The baud rate is S = 3
Mbps/3 Is To MHz. Calculate the humber of levels
(different frequencies), the baud rate, and the
bandwidth.
Solution:
We can have L = 2^3 = 8. The baud rate is S = 3
Mbps/3 = 1 Mbaud. This means that the carrier
frequencies mu Contracture in Equencies), the badd rate, and the bandwidth.
Solution:
We can have L = 2^3 = 8. The badd rate is S = 3
Mbps/3 = 1 Mbaud. This means that the carrier
frequencies must be 1 MHz apart ($2\Delta f$ = 1 MHz).
The bandwidth.

Figure 5.8 Bandwidth of MFSK used in Example 5.6

Phase Shift Keying (PSK)

- **In Phase Shift Keying (PSK)**

In PSK, the phase of the carrier signal is varied

to represent the different signal elements Phase Shift Keying (PSK)
In PSK, the phase of the carrier signal is varied
to represent the different signal elements
carrying data. **Phase Shift Keying (PSK)**
In PSK, the phase of the carrier sito
to represent the different sign
carrying data.
Both amplitude and frequency rema **Both amplitude and frequency remain constant.**

• In PSK, the phase of the carrier signal is varied

to represent the different signal elements
 • Both amplitude and frequency remain constant.

• PSK is more common than In PSK, the phase of the carrier signal is varied
to represent the different signal elements
carrying data.
Both amplitude and frequency remain constant.
PSK is more common than ASK and FSK.
However, QAM is the dominant me to represent the different signal
carrying data.
Both amplitude and frequency remain
PSK is more common than ASK and F!
However, QAM is the dominant metho
to analogy conversion.
-
- **PSK is more common than ASK and FSK.**
-

PSK (Conti…)

- The simplest PSK is binary PSK (BPSK).

The simplest PSK is binary PSK (BPSK).

The simplest PSK is binary PSK (BPSK).
- **PSK (Conti...)**

For the simplest PSK is binary PSK (BPSK).

BPSK has only two signal element: one with a phase 0° and the other with a phase of 180°. **PSK (Conti...)**
The simplest PSK is binary PSK (E
BPSK has only two signal element
phase 0^o and the other with a ph
PSK is much more robust than K (Conti...)
lest PSK is binary PSK (BPSK).
and the other with a phase of 180°.
uch more robust than ASK as it is not .
- **PSK (Conti...)**

 The simplest PSK is binary PSK (BPSK).

 BPSK has only two signal element: one with a

phase 0° and the other with a phase of 180°.

 PSK is much more robust than ASK as it is not

that vulnerable to that vulnerable to noise. • The simplest PSK is binary PSK (BPSK).

• BPSK has only two signal element: one with a

phase 0° and the other with a phase of 180°.

• PSK is much more robust than ASK as it is not

that vulnerable to noise.

• The ban
-

 $B = (1+d) \times S$

Figure 5.9 Binary phase shift keying

Figure 5.10 Implementation of BASK

Quadrature PSK (QPSK)

- **Similarly to ASK and FSK (QPSK)**
Similarly to ASK and FSK, PSK can use multiple bits per signal element. Quadrature PSK (QPSK)
Similarly to ASK and FSK, PSK can use
bits per signal element.
Quadrature PSK (OPSK) is used to send
- Quadrature PSK (QPSK)

Similarly to ASK and FSK, PSK can use multiple

bits per signal element.

Quadrature PSK (QPSK) is used to send 2 bits at

a time in each signal element. Quadrature PSK (QPSK)
Similarly to ASK and FSK, PSK can use multipl
bits per signal element.
Quadrature PSK (QPSK) is used to send 2 bits a
a time in each signal element.
OPSK used two separate BPSK modulation: on • Similarly to ASK and FSK, PSK can use multiple
bits per signal element.
• Quadrature PSK (QPSK) is used to send 2 bits at
a time in each signal element.
• QPSK used two separate BPSK modulation: one
is in-phase and the o
- QPSK used two separate BPSK modulation: one
- bits per signal element.

 Quadrature PSK (QPSK) is used to send 2 bits at

a time in each signal element.

 QPSK used two separate BPSK modulation: one

is in-phase and the other is out-of-phase.

 The incoming bits ar Quadrature PSK (QPSK) is used to send 2 bits at
a time in each signal element.
QPSK used two separate BPSK modulation: one
is in-phase and the other is out-of-phase.
The incoming bits are first passed through a
serial-to-p Quadrature PSK (QPSK) is used to send 2 bits at
a time in each signal element.
QPSK used two separate BPSK modulation: one
is in-phase and the other is out-of-phase.
The incoming bits are first passed through a
serial-to-p

QPSK (Conti…)

- If the duration of each bit in the incoming signal
If the duration of each bit in the incoming signal
In The duration of each bit sent to the QPSK (Conti...)
If the duration of each bit in the incoming signal
is 7 then the duration of each bit sent to the
corresponding BPSK signal is 27. **corresponding BPSK** (Conti...)
 Example 1 If the duration of each bit in the incoming signal is 7 then the duration of each bit sent to the corresponding BPSK signal is 27.
 Example 1 This means that the bit of each B **Example 18 CENTA CONCICE:**
If the duration of each bit in the incoming signal
is T then the duration of each bit sent to the
corresponding BPSK signal is $2T$.
This means that the bit of each BPSK signal has
one-half t **The two composite signal**

• If the duration of each bit in the incoming signal

is *T* then the duration of each bit sent to the

corresponding BPSK signal is 27 .

• This means that the bit of each BPSK signal has

on
-
- If the duration of each bit in the incoming signal
is 7 then the duration of each bit sent to the
corresponding BPSK signal is 27.
This means that the bit of each BPSK signal has
one-half the frequency of the original sign phases. corresponding BPSK signal is 27.

• This means that the bit of each BPSK signal has

one-half the frequency of the original signal.

• The two composite signals created by each

multiplier have the same frequency but diff This means that the bit of each BPSK signal has
one-half the frequency of the original signal.
The two composite signals created by each
multiplier have the same frequency but different
phases.
When they are added, the re of each BPSK signal has
the original signal.
nals created by each
frequency but different
ne resultant signal has
, -45^o, 135^o, and -135^o n BPSK signal has
riginal signal.
created by each
ency but different
sultant signal has
, 135°, and -135° Solar Signal

doby each

but different

differ This means that the bit of each Brone-half the frequency of the origin
The two composite signals crea
multiplier have the same frequency
phases.
When they are added, the resulta
four possible phases: 45° , -45° ,
-

Figure 5.11 QPSK and its implementation

QPSK (Conti…)

**Example 5.7: Find the bandwidth for a signal
Example 5.7: Find the bandwidth for a signal
transmitting at 12 Mbps for QPSK. The value of d the Caucal Condination CPSK (Contination**
 Example 5.7: Find the bandwidth for a signal

transmitting at 12 Mbps for QPSK. The value of d

= 0. **Example 5.7:** Find the ba
transmitting at 12 Mbps for = 0. Example 5.7: Find the bandwidth for a signal
transmitting at 12 Mbps for QPSK. The value of d
= 0.
Solution:
For QPSK, 2 bits is carried by one signal element.
This means that r = 2. So the signal rate (baud
rate) is $S = N$

Solution:

Example 5.7: Find the bandwidth for a signal
transmitting at 12 Mbps for QPSK. The value of d
= 0.
Solution:
For QPSK, 2 bits is carried by one signal element.
This means that r = 2. So the signal rate (baud
rate) is S = transmitting at 12 Mbps for QPSK. The value of d
= 0.
Solution:
For QPSK, 2 bits is carried by one signal element.
This means that r = 2. So the signal rate (baud
rate) is S = N × (1/r) = 6 Mbaud. With a value of
d = 0, w = 0.
Solution:
For QPSK, 2 bits is carried by one signal element.
This means that r = 2. So the signal rate (baud
rate) is S = N × (1/r) = 6 Mbaud. With a value of
d = 0, we have B = S = 6 MHz.

Constellation Diagram

- It Constellation Diagram

It helps in defining the amplitude and phase of a

It helps in defining the amplitude and phase of a

signal element particularly when two carrier **Signal Exercise Inter-**
Signal element particularly when two carrier
signal element particularly when two carrier
signals (in-phase and out-of-phase) are used. **Signal Constellation Diagram**
It helps in defining the amplitude and phase of a
signal element particularly when two carrier
signals (in-phase and out-of-phase) are used.
It is useful when dealing with multi-level ASK. It helps in defining the amplitude and phase of a

It helps in defining the amplitude and phase of a

signals (in-phase and out-of-phase) are used.

It is useful when dealing with multi-level ASK,

PSK or QAM. ■ It helps in defining the amplitude and phase of a
signal element particularly when two carrier
signals (in-phase and out-of-phase) are used.
■ It is useful when dealing with multi-level ASK,
PSK or QAM.
■ A signal eleme It helps in defining the amplitude and phase of a
signal element particularly when two carrier
signals (in-phase and out-of-phase) are used.
It is useful when dealing with multi-level ASK,
PSK or QAM.
A signal element is r
- PSK or QAM.
-
- Signals (in-phase and out-of-phase) are used.

 It is useful when dealing with multi-level ASK,

PSK or QAM.

 A signal element is represented by a dot and

bit(s) it carry is/are written next to it.

 It has two axes: It is useful when dealing with multi-level ASK,
PSK or QAM.
A signal element is represented by a dot and
bit(s) it carry is/are written next to it.
It has two axes: X-axis (horizontal) represents
in-phase carrier, and Y-ax It is useful when dealing with multi-le
PSK or QAM.
A signal element is represented by a
bit(s) it carry is/are written next to it.
It has two axes: X-axis (horizontal) re
in-phase carrier, and Y-axis (vertical) re
out-of-

- For each point on the diagram (Conti...)
For each point on the diagram, four pieces of information can be deduced: Constellation Diagram (Conti...)
For each point on the diagram, four pieces
information can be deduced:
• The projection of the point on X-axis defines Constellation Diagram (Conti...)

The projection of the diagram, four pieces of

The projection of the point on X-axis defines the

peak amplitude of in-phase component origonal Continution Continuty
origonal control continuity
formation can be deduced:
The projection of the point on X-axis defines the
peak amplitude of in-phase component
The projection of the point on Y-axis defines the r each point on the diagram, four pieces of
ormation can be deduced:
The projection of the point on X-axis defines the
peak amplitude of in-phase component
The projection of the point on Y-axis defines the
peak amplitude o
	-
	- **The projection of the point on Y-axis defines the** of each point off the diagram, four pieces of

	formation can be deduced:

	• The projection of the point on X-axis defines the

	peak amplitude of in-phase component

	• The projection of the point on Y-axis defines the

	peak ormation can be deduced:
The projection of the point on X-axis defines the
peak amplitude of in-phase component
The projection of the point on Y-axis defines the
peak amplitude of out-of-phase component
The line that conne
	-
	- The projection or the point on x-axis defines the
peak amplitude of in-phase component

	 The projection of the point on Y-axis defines the

	peak amplitude of out-of-phase component

	 The line that connects the point t peak amplitude or in-phase component
The projection of the point on Y-axis defines th
peak amplitude of out-of-phase component
The line that connects the point to the orig
defines the peak amplitude of the signal
The angle

Figure 5.12 Concept of a constellation diagram

Example 5.8: Show the constellation (Conti...)
Example 5.8: Show the constellation diagrams for
an ASK (OOK), BPSK, and QPSK signals. **and Ask (Constellation Diagram (Conti...)**
Example 5.8: Show the constellation diagrams for
an ASK (OOK), BPSK, and QPSK signals.
Solution:

Solution:

Figure 5.13 shows the three constellation diagrams.

Figure 5.13 Three constellation diagrams

-
- Constellation Diagram
• For ASK:
• Only in-phase carrier is used, Constellation Diagram (Conti...)

For ASK:

• Only in-phase carrier is used, therefore, the two

points should be on the X-axis

– Pinam A has an amplitude of 0V utils binam 1 Lace Constellation Diagram (Conti...)
The ASK:
Only in-phase carrier is used, therefore, the two
points should be on the X-axis
Binary 0 has an amplitude of 0V while binary 1
- Constellation Diagram (Conti...)

For ASK:

 Only in-phase carrier is used, therefore, the two

points should be on the X-axis

 Binary 0 has an amplitude of 0V while binary 1

has an amplitude of 1V

 The points are lo __ Constellation Diagram (Conti...)
r ASK:
Only in-phase carrier is used, therefore, the two
points should be on the X-axis
Binary 0 has an amplitude of 0V while binary
has an amplitude of 1V
The points are located at the • For ASK:

• Only in-phase carrier is used,

points should be on the X-axis

• Binary 0 has an amplitude of

has an amplitude of 1V

• The points are located at the of

• For BPSK:

• Uses only an in-phase carrier For ASK:

• Only in-phase carrier is used, therefore, the two

points should be on the X-axis

• Binary 0 has an amplitude of 0V while binary 1

has an amplitude of 1V

• The points are located at the origin and at 1 unit Only in-phase carrier is used, thereform points should be on the X-axis
Binary 0 has an amplitude of 0V wh
has an amplitude of 1V
The points are located at the origin ar
r BPSK:
Uses only an in-phase carrier creatin
of sig
	- The points are located at the origin and at 1 unit
- -
- points should be on the X-axis

 Binary 0 has an amplitude of 0V while binary 1

has an amplitude of 1V

 The points are located at the origin and at 1 unit

For BPSK:

 Uses only an in-phase carrier creating two types • One with amplitude 1V and phase 0° (in-phase) Binary 0 has an amplitude of 0V while binary 1
has an amplitude of 1V
The points are located at the origin and at 1 unit
r BPSK:
Uses only an in-phase carrier creating two types
of signal elements
One with amplitude 1V and and other amplitude of 1V and phase 180° (outof-phase)

-
- Constellation Diagram
• For QPSK:
• It uses two carrier; one in-ph It uses two carrier; one in-phase while the other
It uses two carrier; one in-phase while the other
out-of-phase
In Fash using is made of two combined simeles out-of-phase
	- Constellation Diagram (Conti...)

	For QPSK:

	For QPSK:

	The It uses two carrier; one in-phase while the other

	out-of-phase

	Fach point is made of two combined signal

	elements, both with an amplitude of 1V

	Fore algority Constellation Diagram (Conti...)

	r QPSK:

	It uses two carrier; one in-phase while the other

	out-of-phase

	Each point is made of two combined signal

	elements, both with an amplitude of 1V

	One element is represented by i
	- One element is represented by in-phase carrier r QPSK:
It uses two carrier; one in-phase while the other
out-of-phase
Each point is made of two combined signal
elements, both with an amplitude of 1V
One element is represented by in-phase carrier
while the other is repr carrier ■ It uses two carrier; one in-phase while the other

	out-of-phase

	■ Each point is made of two combined signal

	elements, both with an amplitude of 1V

	■ One element is represented by in-phase carrier

	while the other is are different (45^o, 135^o, -135^o, -45^o)
are different is made of two combine
elements, both with an amplitude of 1V
One element is represented by in-phase
while the other is represented by out-
carrier
All points ha made of two combined signal
ith an amplitude of 1V
represented by in-phase carries represented by out-of-phase
the same amplitude but phase, 135°, -135°, -45°) of two combined signal
amplitude of 1V
sented by in-phase carrier
presented by out-of-phase
nme amplitude but phases
, -135°, -45°) ase while the striet
o combined signal
ude of 1V
by in-phase carrier
ed by out-of-phase
nplitude but phases
, -45°)
	- are different (45°, 135°, -135°, -45°)

Quadrature Amplitude Modulation (QAM)

- Quadrature Amplitude Modulation

(QAM)

The modulation schemes discussed so far alter

only one of the three characteristics (amplitude,

frequency, and phase) of a sine wave at a time Quadrature Amplitude Modulation

(QAM)

The modulation schemes discussed so far alter

only one of the three characteristics (amplitude,

frequency, and phase) of a sine wave at a time. Quadrature Amplitude Modulation

(QAM)

The modulation schemes discussed so far alter

only one of the three characteristics (amplitude,

frequency, and phase) of a sine wave at a time.

OAM is the combination of ASK and P Quadrature Amplitude Modulation

(QAM)

The modulation schemes discussed so far alter

only one of the three characteristics (amplitude,

frequency, and phase) of a sine wave at a time.

AM is the combination of ASK and PS
-
- The idea of using two carriers; one in-phase and • The modulation schemes discussed so far alter
only one of the three characteristics (amplitude,
frequency, and phase) of a sine wave at a time.
• QAM is the combination of ASK and PSK
• The idea of using two carriers; on The modulation schemes discussed so far alter
only one of the three characteristics (amplitude,
frequency, and phase) of a sine wave at a time.
QAM is the combination of ASK and PSK
The idea of using two carriers; one in-p QAM. • QAM is the combination of ASK and PSK

• The idea of using two carriers; one in-phase and

other out-of-phase, with different amplitude

levels for each carrier is the concept behind

QAM.

• The possible variations of Q QAM is the combination of ASK and PSK
The idea of using two carriers; one in-phase and
other out-of-phase, with different amplitude
levels for each carrier is the concept behind
QAM.
The possible variations of QAM are nume
-

Figure 5.14 Constellation diagrams for some QAMs

QAM (Conti…)

-
- **CAM (Conti...)**

Figure 5.14a:

 4-QAM Four different signal

using unipolar NP7 signal to QAM (Conti...)
Figure 5.14a:
• 4-QAM – Four different signal element types
using unipolar NRZ signal to modulate each
carrier Same as ASK (OOK) __ QAM (Conti...)
|ure 5.14a:
4-QAM – Four different signal element types
using unipolar NRZ signal to modulate each
carrier, Same as ASK (OOK) Lampdare Continuity

1998 - Carrier S. 143:

4-QAM – Four different signal element types

1998 - using unipolar NRZ signal to modulate each

1998 - Carrier, Same as ASK (OOK)

1998 - Palar NPZ, but exactly same as - QAM (Conti...)

Figure 5.14a:

- 4-QAM – Four different signal

using unipolar NRZ signal to

carrier, Same as ASK (OOK)

- Figure 5.14b:

- 4-QAM – Uses polar NRZ, but

opsk • Figure 5.14a:

• 4-QAM – Four different signal

using unipolar NRZ signal to

carrier, Same as ASK (OOK)

• Figure 5.14b:

• 4-QAM – Uses polar NRZ, but

QPSK

• Figure 5.14c:

• 4-QAM – Uses a signal with two

modulate - 19ure 5.14a:

■ 4-QAM – Four different signal element types

using unipolar NRZ signal to modulate each

carrier, Same as ASK (OOK)

Figure 5.14b:

■ 4-QAM – Uses polar NRZ, but exactly same as

QPSK

Figure 5.14c:

■ 4 4-QAM – Four different signal element types
using unipolar NRZ signal to modulate each
carrier, Same as ASK (OOK)
yure 5.14b:
4-QAM – Uses polar NRZ, but exactly same as
QPSK
yure 5.14c:
4-QAM – J signal with two positive
- - 4-QAM Uses polar NRZ, but exactly same as QPSK
-
- using unipolar NRZ signal to

carrier, Same as ASK (OOK)

 Figure 5.14b:

 4-QAM Uses polar NRZ, but

QPSK

 Figure 5.14c:

 4-QAM Uses a signal with two

modulate each of the two carriers

 Figure 5.14d:

 16-QA
-
- -carrier, Same as ASK (OOK)

Figure 5.14b:

 4-QAM Uses polar NRZ, but exactly same as

QPSK

Figure 5.14c:

 4-QAM Uses a signal with two positive levels to

modulate each of the two carriers

Figure 5.14d:

 16-QA yure 5.14b:
4-QAM – Uses polar NRZ, but exac
QPSK
yure 5.14c:
4-QAM – Uses a signal with two posit
modulate each of the two carriers
yure 5.14d:
16-QAM – a signal with eight level, 1
and four negative

Analog-to-Analog Conversion

- **Analog-to-Analog Conversion
• Analog-to-analog conversion is also known as
• analog modulation** Analog-to-Analog Conve
Analog-to-analog conversion is
analog modulation
It the representation of the anal
- **It the representation**
 It the representation
 It the representation of the analog information

(data, message) by an analog signal Analog-to-Analog Conversion
Analog-to-analog conversion is also known as
analog modulation
It the representation of the analog information
(data, message) by an analog signal
It is required if the medium is band-pass in - Analog-to-analog conversion is also known as

analog modulation

- It the representation of the analog information

(data, message) by an analog signal

- It is required if the medium is band-pass in

nature or only band
- It is required if the medium is band-pass in
- analog modulation

 It the representation of the analog information

(data, message) by an analog signal

 It is required if the medium is band-pass in

nature or only band-pass channel is available

 For example, govt. It the representation of the analog information
(data, message) by an analog signal
It is required if the medium is band-pass in
nature or only band-pass channel is available
For example, govt. assigns narrow bandwidth to
 It the representation of the analog information
(data, message) by an analog signal
It is required if the medium is band-pass in
nature or only band-pass channel is available
For example, govt. assigns narrow bandwidth to

Analog-to-Analog Conversion (Conti…)

- To able to listen to different stations, the low-

To able to listen to different stations, the low-

pass signals need to be shifted (modulated), Analog-to-Analog Conversion (Conti...)
To able to listen to different stations, the low-
pass signals need to be shifted (modulated),
each to a different range. Analog-to-Analog Conversion (Con
To able to listen to different stations, the longless signals need to be shifted (modulate
each to a different range.
Analog Modulation can be accomplished in the Analog-to-Analog Conversion (Conti...)

• To able to listen to different stations, the low-

pass signals need to be shifted (modulated),

each to a different range.

• Analog Modulation can be accomplished in three

ways: To able to listen to different stations, the low-

Dass signals need to be shifted (modulated),

Pach to a different range.

Analog Modulation can be accomplished in three

vays:

• Amplitude Modulation (AM)

• Frequency M Frequency Modulation (FM)

Frequency Modulation Can be accomplished in three

Nanalog Modulation can be accomplished in three

vays:

Frequency Modulation (AM)

Frequency Modulation (FM)

Phase Modulation (PM)
- ways: each to a different range.
Analog Modulation can be accomplished in thin
ways:
• Amplitude Modulation (AM)
• Frequency Modulation (FM)
• Phase Modulation (PM)
	-
	-
	-

Figure 5.15 Types of analog-to-analog modulation

Amplitude Modulation (AM)

- In Amplitude Modulation (AM)
In AM transmission, the carrier signal is
modulated to that its amplitude varies with the **EXECUTE: Amplitude Modulation (AM)**
In AM transmission, the carrier signal is
modulated to that its amplitude varies with the
changing amplitude of the modulating signal. **Examplifude Modulation (AM)**
In AM transmission, the carrier signal is
modulated to that its amplitude varies with the
changing amplitude of the modulating signal.
The frequency and phase of the carrier signal **Example 12**
 **The frequency and phase of the carrier signal is

modulated to that its amplitude varies with the

changing amplitude of the modulating signal.

The frequency and phase of the carrier signal

remain the same Example 12 Amplitude Modulation (AM)**
In AM transmission, the carrier
modulated to that its amplitude varie
changing amplitude of the modulating
The frequency and phase of the ca
remain the same.
The modulating signal is The modulation (APT)

• In AM transmission, the carrier signal is

modulated to that its amplitude varies with the

changing amplitude of the modulating signal.

• The frequency and phase of the carrier signal

• The modul modulated to that its amplitude varies with the
changing amplitude of the modulating signal.
• The frequency and phase of the carrier signal
remain the same.
• The modulating signal is the envelop of the
carrier.
• The req
-
- carrier. changing amplitude of the modulating signal.
The frequency and phase of the carrier signal
remain the same.
The modulating signal is the envelop of the
carrier.
The required bandwidth is 2B, where B is the
bandwidth of the The frequency and phase of the carrier signal

The modulating signal is the envelop of the

The required bandwidth is 2B, where B is the

bandwidth of the modulating signal.

AM is normally implement by a simple multiplier
-
-

Figure 5.16 Amplitude modulation

AM (Conti…)

- AM (Conti...)
The bandwidth of an audio signal (speed and music) is usually 5KHz. M (Conti...)
The bandwidth of an audio signal (speed
music) is usually 5KHz.
AM radio station requires bandwidth of 1
- AM (Conti...)

 The bandwidth of an audio signal (speed and

music) is usually 5KHz.

 AM radio station requires bandwidth of 10KHz

and Federal Communications Commission (FCC) M (Conti...)
The bandwidth of an audio signal (speed and
music) is usually 5KHz.
AM radio station requires bandwidth of 10KHz
and Federal Communications Commission (FCC)
allocate it for each AM station. allocate it for each AM station. • The bandwidth of an audio signal (speed and

music) is usually 5KHz.

• AM radio station requires bandwidth of 10KHz

and Federal Communications Commission (FCC)

allocate it for each AM station.

• AM stations are allow
- The bandwidth of an audio signal (speed and
music) is usually 5KHz.
AM radio station requires bandwidth of 10KHz
and Federal Communications Commission (FCC)
allocate it for each AM station.
AM stations are allowed to selec music) is usually 5KHz.
AM radio station requires bandwidth o
and Federal Communications Commissic
allocate it for each AM station.
AM stations are allowed to select
frequencies anywhere between 530
1700KHz (1.7 MHz).
Stat ■ AM radio station requires bandwidth of 10KHz

and Federal Communications Commission (FCC)

allocate it for each AM station.

■ AM stations are allowed to select carrier

frequencies anywhere between 530KHz to

1700KHz (and Federal Communications Commission (FCC)
allocate it for each AM station.
AM stations are allowed to select carrier
frequencies anywhere between 530KHz to
1700KHz (1.7 MHz).
Stations must be separated by at least 10KHz
-

Figure 5.17 AM band allocation

Frequency Modulation (FM)

- In Frequency Modulation (FM)

In FM transmission, the frequency of the carrier

signal is modulated to follow the changing

amplitude of the modulating signal Frequency Modulation (FM)
In FM transmission, the frequency of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal. Frequency Modulation (FM)

In FM transmission, the frequency of the carrier

signal is modulated to follow the changing

amplitude of the modulating signal.

The peak amplitude and phase of the carrier The peak amplitude and phase of the carrier

The peak amplitude and phase of the carrier

Fhe peak amplitude and phase of the carrier

signal remains the same. Frequency Modulation (FM)
In FM transmission, the frequency of the car
signal is modulated to follow the chang
amplitude of the modulating signal.
The peak amplitude and phase of the car
signal remains the same.
The total The The total bandwidth requestion (TTT)

The FM transmission, the frequency of the carrier

signal is modulated to follow the changing

The peak amplitude and phase of the carrier

signal remains the same.

The total band
-
- In FM transmission, the frequency of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal.
The peak amplitude and phase of the carrier
signal remains the same.
The total bandwidth requ In FM transmission, the frequency of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal.
The peak amplitude and phase of the carrier
signal remains the same.
The total bandwidth req **Examplitude of the modulating signal.**
 FM is peak amplitude and phase of the carrier signal remains the same.
 FM is normally implemented by using a voltage-controlled oscillator as with FSK. The peak amplitude and phase of the carrier
signal remains the same.
The total bandwidth required for FM can be
determined from the bandwidth of the audio
signal: $B_{FM} = 2(1 + \beta)B$. Where β is usually 4.
FM is normally
-

Amplitude

Figure 5.18 Frequency modulation

FM (Conti…)

- The Bandwidth of an audio signal (speech and music) broadcast in stereo is almost 15KHz. **EXEC FM (Conti...)**
The bandwidth of an audio signal (speech and
music) broadcast in stereo is almost 15KHz.
The FCC allows 200KHz (0.2MHz) for each
- **FM** (Conti...)
 **The bandwidth of an audio signal (speech and music) broadcast in stereo is almost 15KHz.

The FCC allows 200KHz (0.2MHz) for each station, i.e.** β =4 with some extra guard band. FM (Conti...)
The bandwidth of an audio signal (speech and
music) broadcast in stereo is almost 15KHz.
The FCC allows 200KHz (0.2MHz) for each
station, i.e. β=4 with some extra guard band.
FM stations are allowed carrier **The bandwidth of an audio signal (speech and music) broadcast in stereo is almost 15KHz.**
 The FCC allows 200KHz (0.2MHz) for each station, i.e. β=4 with some extra guard band.
 FM stations are allowed carrier freque
- FM stations are allowed carrier frequencies
- music) broadcast in stereo is almost 15KHz.

 The FCC allows 200KHz (0.2MHz) for each

station, i.e. β =4 with some extra guard band.

 FM stations are allowed carrier frequencies

anywhere between 88 and 108 MHz.

 The FCC allows 200KHz (0.2MHz) for each
station, i.e. β =4 with some extra guard band.
FM stations are allowed carrier frequencies
anywhere between 88 and 108 MHz.
Stations must be separated by at least 10KHz to
keep th

Figure 5.19 FM band allocation

Phase Modulation (PM)

- **In Phase Modulation (PM)**

In PM transmission, the phase of the carrier

signal is modulated to follow the changing

amplitude of the modulating signal Phase Modulation (PM)
In PM transmission, the phase of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal. **EXECUTE: Phase Modulation (PM)**
In PM transmission, the phase of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal.
The peak amplitude and frequency of the carrier The phase Modulation (PM)

The phase of the carrier

signal is modulated to follow the changing

amplitude of the modulating signal.

The peak amplitude and frequency of the carrier

frequency remains the same. In PM transmission, the phase of the carrier
signal is modulated to follow the changing
amplitude of the modulating signal.
The peak amplitude and frequency of the carrier
frequency remains the same.
It can be proved that In PM transmission, the phase of the carrively
signal is modulated to follow the changir
amplitude of the modulating signal.
The peak amplitude and frequency of the carrivel
frequency remains the same.
It can be proved tha
- frequency remains the same.
-
- In FM, the instantaneous change in the carrier

In FM, the instantaneous change in the carrier

In FM, the instantaneous change in the carrier

frequency is proportional to the amplitude of the

In FM, the instantaneous ch The peak amplitude and frequency of the carrier
frequency remains the same.
It can be proved that mathematically PM is same
as FM with only one difference.
In FM, the instantaneous change in the carrier
frequency is propor The peak amplitude and frequency of the ca
frequency remains the same.
It can be proved that mathematically PM is s
as FM with only one difference.
In FM, the instantaneous change in the ca
frequency is proportional to the

PM (Conti…)

- IN PM (Conti...)
In PM the instantaneous change in the carrier
frequency is proportional to the derivative of the FRIM (Conti...)
The PM the instantaneous change in the carrier
frequency is proportional to the derivative of the
amplitude of the modulating signal. **PM (Conti...)**

In PM the instantaneous change in the carrier

frequency is proportional to the derivative of the

amplitude of the modulating signal.

PM is normally implemented by using a voltage PM (Conti...)

• In PM the instantaneous change in the carrier

frequency is proportional to the derivative of the

amplitude of the modulating signal.

• PM is normally implemented by using a voltage

controlled oscillato ■ In PM the instantaneous change in the carrier
frequency is proportional to the derivative of the
amplitude of the modulating signal.
■ PM is normally implemented by using a voltage
controlled oscillator along with a de
- controlled oscillator along with a derivative.
- In PM the instantaneous change in the carrier
frequency is proportional to the derivative of the
amplitude of the modulating signal.
PM is normally implemented by using a voltage
controlled oscillator along with a derivat frequency is proportional to the derivative of the
amplitude of the modulating signal.
PM is normally implemented by using a voltage
controlled oscillator along with a derivative.
The total bandwidth required for FM can b often.

Amplitude

Figure 5.20 Phase modulation