5.5 LINE CODING REVIEW : LINE CODING AND ITS PROPERTIES

The digital data can be transmitted by various transmission or line codes such as on-off, polar, bipolar and so on. This is called line-coding*. Each type of line-code has its advantages and disadvantages.

Thus, among other desirable properties, a line code must have the following properties:

1. Transmission bandwidth

For a line-code, the transmission bandwidth must be as small as possible.

2. Power efficiency

For a given bandwidth and a specified detection error probability, the transmitted power for a line code should be as small as possible.

3. Error detection and correction capability

It must be possible to detect and preferably correct detection errors. For example, in a bipolar case, a signal error will cause bipolar violation and thus can easily be detected.

4. Favourable power spectral density

It is desirable to have zero power spectral density (PSD) at $\omega = 0$ (i.e., dc) since ac coupling and transformers are used at the repeaters. Significant power in low-frequency components causes dc wander in the pulse stream when ac coupling is used. The a.c. coupling is required since the dc paths provided by the cable pairs between the repeater sites are used to transmit the power required to operate the repeaters.

5. Adequate timing content

It must be possible to extract timing or clock information from the signal.

6. Transparency

It must be possible to transmit a digital signal correctly regardless the pattern of 1's and 0's.

5.6 VARIOUS PAM FORMATS OR LINE CODES

Some of the important PAM formats or line coding techniques are as under:

(i) Non-return to zero (NRZ) and return to zero (RZ) unipolar format.

(ii) NRZ and RZ polar format.

(iii) Non-return to zero bipolar format.

(iv) Manchester format.

(v) Polar quaternary NRZ format.

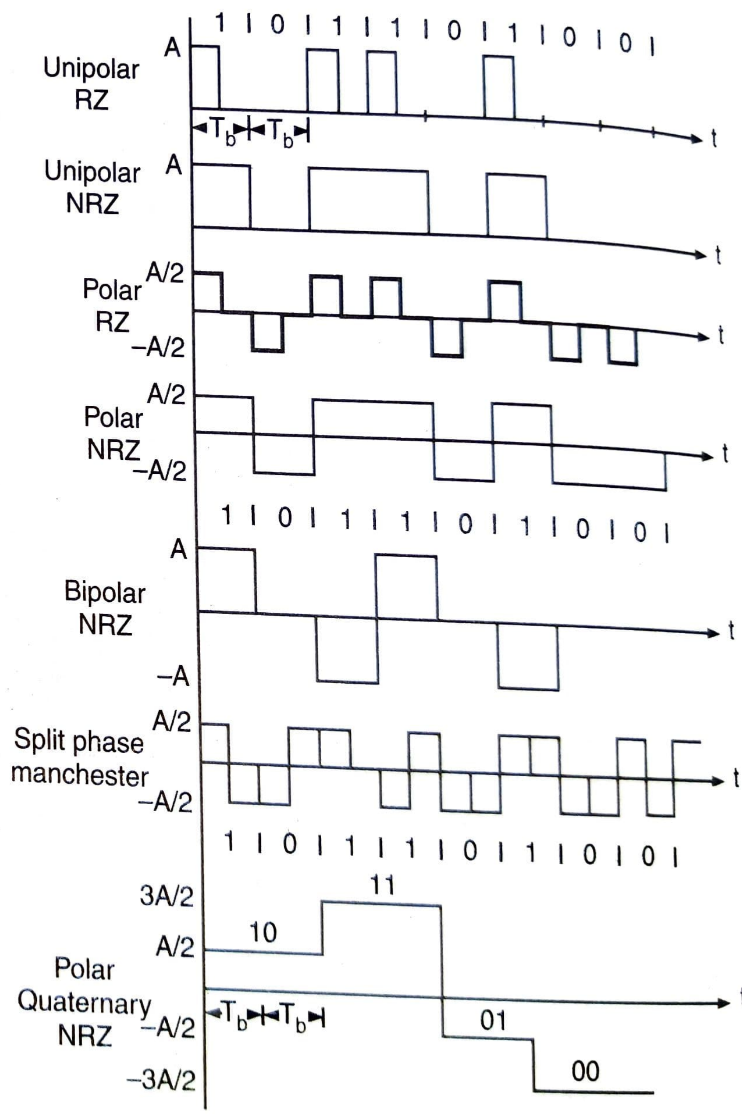


Fig. 5.8. Various digital PAM signals formats (a) Unipolar RZ (b) Unipolar NRZ (c) Polar RZ (d) Polar NRZ (e) Bipolar NRZ (f) Split phase Manchester (g) Polar quaternary NRZ

*Digital line encoding involves converting standard logic levels (TTL, CMOS, and the like) to a form more suitable to telephone line transmission.

All the formats have been shown for a binary message 10110100. Figure 5.8 shows various PAM formats or line codes.

DO YOU KNOW?

Binary 1's are represented by alternately positive or negative values. The binary 0 is represented by a zero level. The term pseudoternary refers to the use of three encoded signal levels to represent two-level (binary) data. This is also called alternate mark inversion (AMI) signaling.

5.7 UNIPOLAR RZ AND NRZ

1. Definition

In unipolar format, the waveform has a single polarity. The waveform can have +5 or +12 volts when high. The waveform is simple on-off.

2. Unipolar RZ : Waveform and Expression

In the unipolar RZ form, the waveform has zero value when symbol '0' is transmitted and waveform has 'A' volts when '1' is transmitted. In RZ form, the 'A' volts is present for $T_b/2$ period if symbol '1' is transmitted and for remaining $T_b/2$, waveform returns to zero value, i.e., for unipolar RZ form, we have

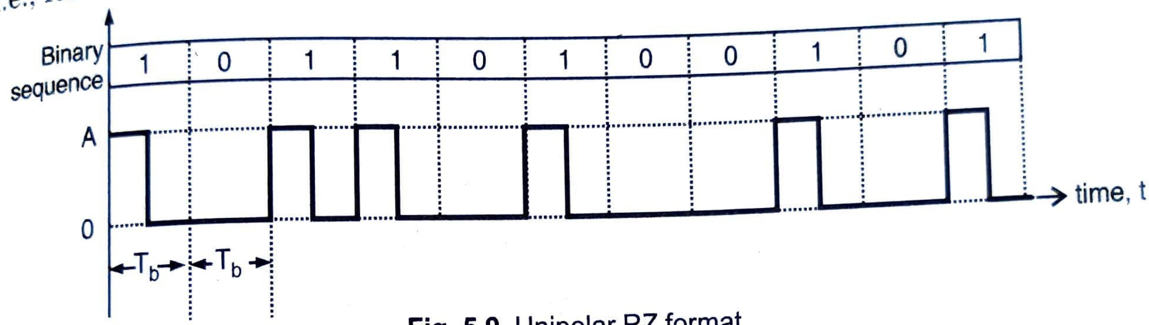


Fig. 5.9. Unipolar RZ format

If symbol '1' is transmitted, then we have

$$x(t) = \begin{cases} A \text{ for } 0 \le t < T_b/2 & \text{(Half interval)} \\ 0 \text{ for } T_b/2 \le t < T_b & \text{(Half interval)} \end{cases} \quad ....(5.7)$$

and if symbol '0' is transmitted, then

$$x(t) = 0 \quad \text{for} \quad 0 \le t < T_b \quad \text{(complete interval)} \quad ...(5.8)$$

Hence, in unipolar RZ format, each pulse returns to a zero value. Figure 5.9 shows this signal format.

3. Unipolar NRZ: Waveform and Expression

A unipolar NRZ (i.e., not return to zero) format is shown in figure 5.10. When symbol '1' is to be transmitted, the signal has 'A' volts for full duration. When symbol '0' is to be transmitted, the signal has zero volts (i.e. no signal) for complete symbol duration.

Thus, for unipolar NRZ format,

If symbol '1' is transmitted, we have

$$x(t) = A \quad \text{for} \quad 0 \le t < T_b \quad \text{(complete interval)} \quad ...(5.9)$$

If symbol '0' is transmitted, we have

$$x(t) = 0 \quad \text{for} \quad 0 \le t < T_b \quad \text{(complete interval)} \quad ...(5.10)$$

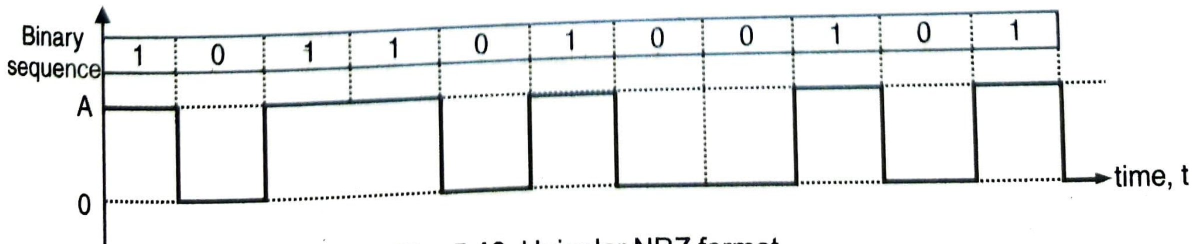


Fig. 5.10. Unipolar NRZ format

4. Important Points

(i) For NRZ format, it may be observed that the pulse does not return to zero on its own. If symbol '0' is to be transmitted, then pulse becomes zero.

(ii) Internal computer waveforms are usually of unipolar NRZ type.

(iii) Because, there is no separation between the pulses, therefore, the receiver needs synchronization to detect unipolar NRZ pulse.

(iv) As compared to RZ format, NRZ pulse width (pulse to pulse interval is same) is more. Thus, energy of the pulse is more.

(v) However, unipolar format has some average DC value. This DC value does not carry any information.

5.8 POLAR RZ AND NRZ*

1. Polar RZ : Waveform and Expression

In the polar RZ format, symbol '1' is represented by positive voltage polarity whereas symbol '0' is represented by negative voltage polarity. Because this is RZ format, the pulse is transmitted only for half duration. Thus, for polar RZ, if symbol '1' is transmitted, then

$$x(t) = \begin{cases} +\dfrac{A}{2} & \text{for } 0 \le t < T_b/2 \\ 0 & \text{for } T_b/2 \le t < T_b \end{cases} \qquad \ldots(5.11)$$

and if symbol '0' is transmitted, then

$$x(t) = \begin{cases} -\dfrac{A}{2} & \text{for } 0 \le t < T_b/2 \\ 0 & \text{for } T_b/2 \le t < T_b \end{cases} \qquad \ldots(5.12)$$

Polar RZ waveform has been shown in figure 5.11.

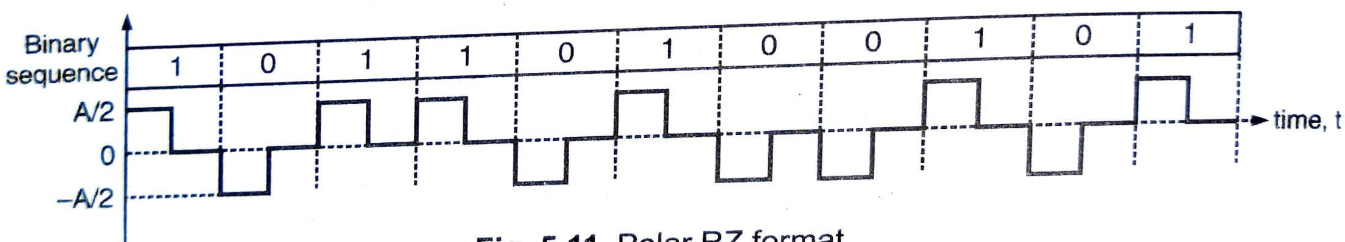


Fig. 5.11. Polar RZ format

2. Polar NRZ : Waveform and Expression

The polar NRZ is shown in figure 5.12. In polar NRZ format, symbol '1' is represented by positive polarity whereas symbol '0' is represented by negative polarity. These polarities are maintained over the complete pulse duration i.e., for polar NRZ, we have

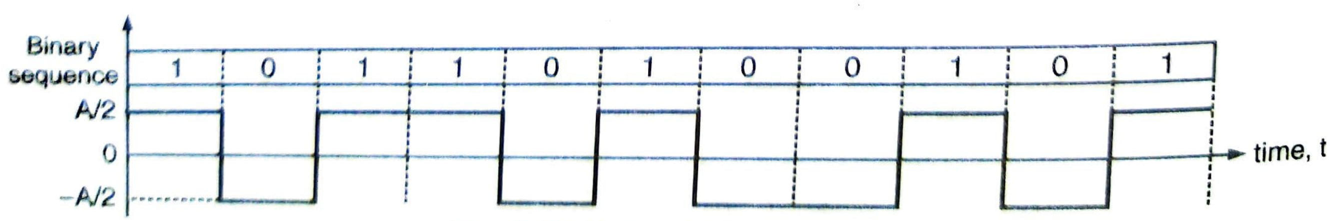


Fig. 5.12. Polar NRZ format

* The duty cycle of a binary pulse can be used to categorize the type of transmission. If the binary pulse is maintained for the entire bit time, this is called non return to zero (NRZ). If the active time of the binary pulse is less than 100%. of the bit time, this is called return to zero (RZ).

If symbol '1' is transmitted, then

$$x(t) = +\frac{A}{2} \quad \text{for} \quad 0 \le t < T_b \qquad ...(5.13)$$

and if symbol '0' is transmitted, then

$$x(t) = -\frac{A}{2} \quad \text{for} \quad 0 \le t < T_b \qquad ...(5.14)$$

Important Points

(i) Since polar RZ and NRZ formats are bipolar, therefore, the average DC value is minimum in these waveforms.

(ii) If probabilities of occurrence of symbols '1' and '0' are same, then average DC components of the waveform would be zero.

5.9 BIPOLAR NRZ [ALTERNATE MARK INVERSION (AMI)]

(JNTU, Hyderabad, Sem. Exam., 2007-08)

1. Definition

In this format, the successive '1's are represented by pulses with alternate polarity and '0's are represented by no pulses.

2. Waveform

Figure 5.13 illustrates the Bipolar NRZ or AMI waveform. If there are even number of 1's, the DC component of the waveform would be zero. The advantage of this format is that the ambiguities due to transmission sign inversion are eliminated.

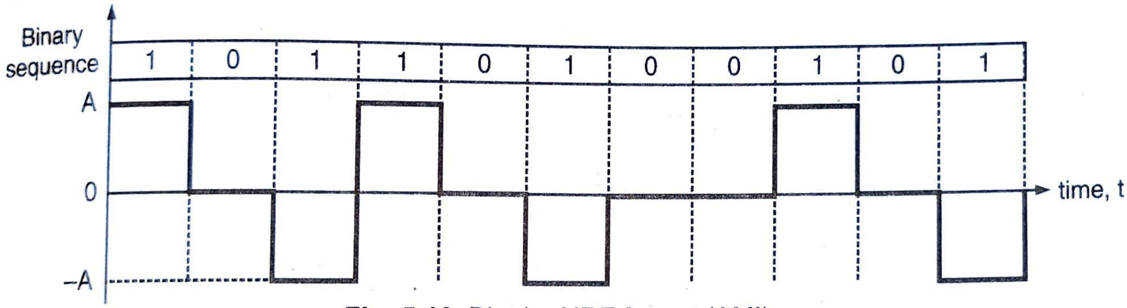


Fig. 5.13. Bipolar NRZ format (AMI)

10 SPLIT PHASE MANCHESTER FORMAT

Definition and Waveform

This type of waveform is shown in figure 5.14. In this case, if symbol '1' is to be transmitted, then a positive half interval pulse is followed by a negative half interval pulse. If symbol '0' is to be transmitted, then a negative half interval pulse is followed by a positive half interval pulse. Hence, for any symbol the pulse takes positive as well as negative value.

> **DO YOU KNOW?**
>
> The various line codes are also known by other names. For example, polar NRZ is also called NRZ-L, where L denotes the normal logical level assignment. Bipolar RZ is also called RZ-AMI, where AMI denotes alternate mark (binary 1) inversion.

Mathematical Expressions

If symbol '1' is to be transmitted, then

$$x(t) = \begin{cases} \dfrac{A}{2} & \text{for } 0 \le t < \dfrac{T_b}{2} \\ -\dfrac{A}{2} & \text{for } \dfrac{T_b}{2} \le t < T_b \end{cases} \qquad ...(5.15)$$

and if symbol '0' is to be transmitted, then

$$x(t) = \begin{cases} -\dfrac{A}{2} & \text{for } 0 \le t < \dfrac{T_b}{2} \\ \dfrac{A}{2} & \text{for } \dfrac{T_b}{2} \le t < T_b \end{cases} \quad ...(5.16)$$

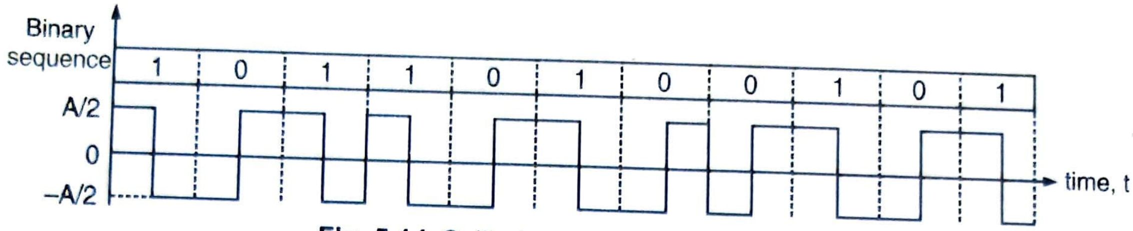


Fig. 5.14. Split phase manchester format

3. Important Points

(i) The primary advantage of this format is that irrespective of the probability of occurrence of symbol '1' and '0' the waveform has zero average value. Therefore by this mode, the power saving is quite more.

(ii) However, the drawback of this format is that it requires absolute sense of polarity at the receiver end.*

5.11 POLAR QUATERNARY NRZ FORMAT

1. Definition and Waveform

Figure 5.15 shows the waveform of this format. This format is derived to reduce the signalling rate 'r'. The message bits are grouped in the blocks of two. Therefore, there are four possible combinations 00, 01, 10 and 11. To these four combinations, four amplitude levels are assigned. The Table 5.1 shows how this can be achieved

DO YOU KNOW?

The Manchester NRZ line code has the advantage of always having a 0-dc value, regardless of the data sequence, but it has twice the bandwidth of the unipolar NRZ or polar NRZ code because the pulses are half the width.

Table 5.1. Polar quaternary NRZ Format: Combinations of bits

Message combination	$x(t) = a_n$
00	$-\frac{3A}{2}$
01	$-\frac{A}{2}$
10	$\frac{A}{2}$
11	$\frac{3A}{2}$

In the waveform of figure 5.15, the first combination of two bits is 10. Thus, from Table 5.1, we may observe that the level should be $\frac{A}{2}$. The second combination in figure 5.15 is 11, hence

*Unipolar and bipolar transmission voltages can be combined with either RZ or NRZ in several ways to achieve a particular line-encoding scheme.

from Table 5.1, the level taken is $\frac{3A}{2}$. Similarly other levels are selected. Hence, for two message bits only one pulse is transmitted with duration $2T_b$, i.e.,

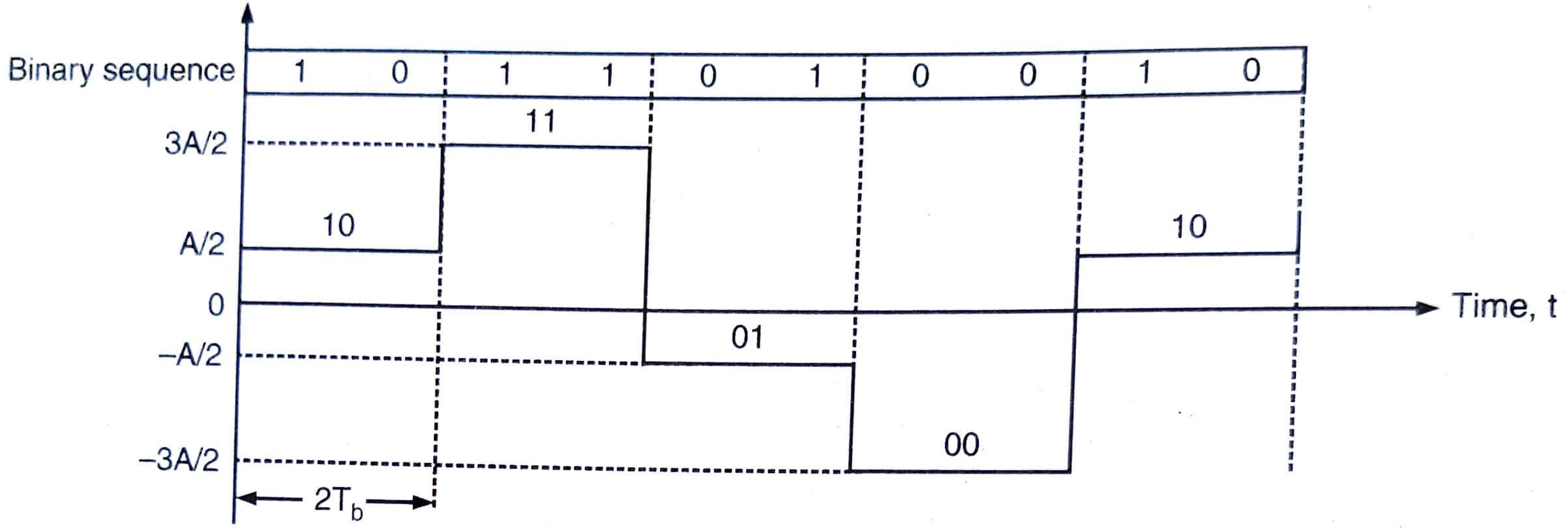


Fig. 5.15. Polar Quaternary NRZ format

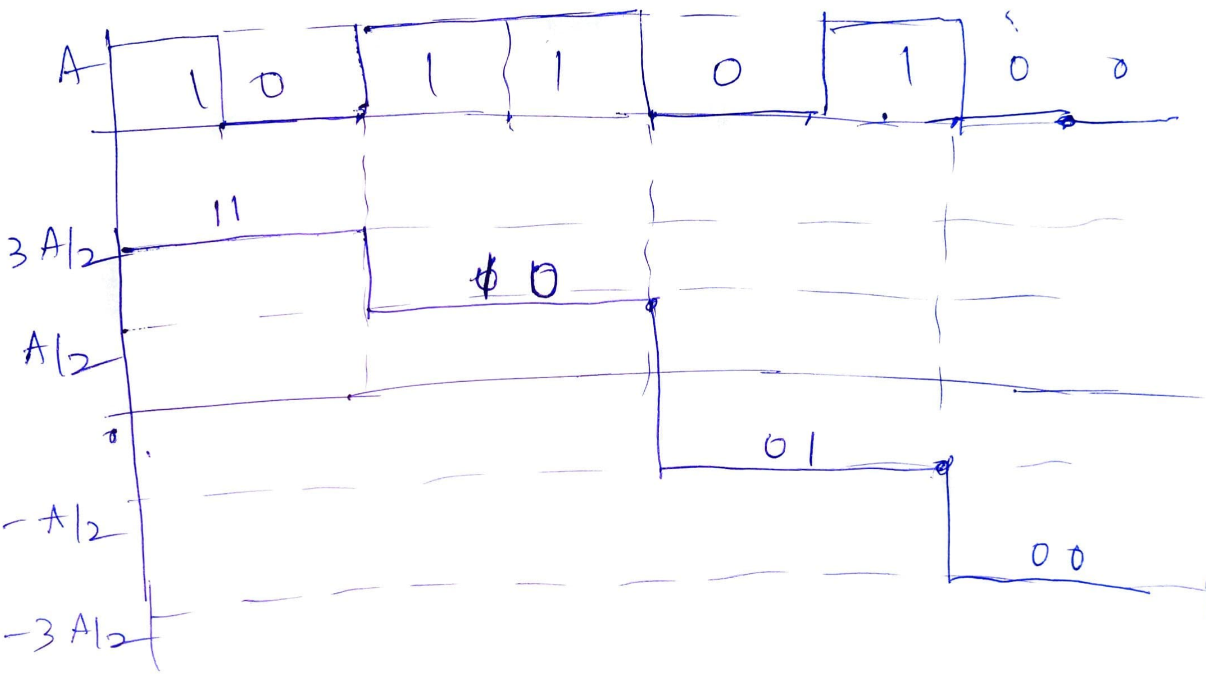
$$T_s = 2T_b$$

and signalling rate is given as,

$$r = \frac{r_b}{2} = \frac{1}{2T_b} \qquad ...(5.17)$$

8. <u>Gray coding</u> (Four level gray code)

Message Sequence	Gray code	Amplitude levels
0 0	0 0	$-3A/2$
0 1	0 1	$-A/2$
1 0	1 1	$+3A/2$
1 1	1 0	$+A/2$



9. <u>M- ary coding</u>

000
001
|
|
111

Signaling rate $r = \frac{r_b}{K}$

where $K = \log_2 M$

(K - successive message bits) are combined to get M- distinct symbols where $M = 2^K$.

For $K = 3$, $M = 8$, there are 8 symbols