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SATELLITE SPREAD SPECTRUM COMMUNICATION

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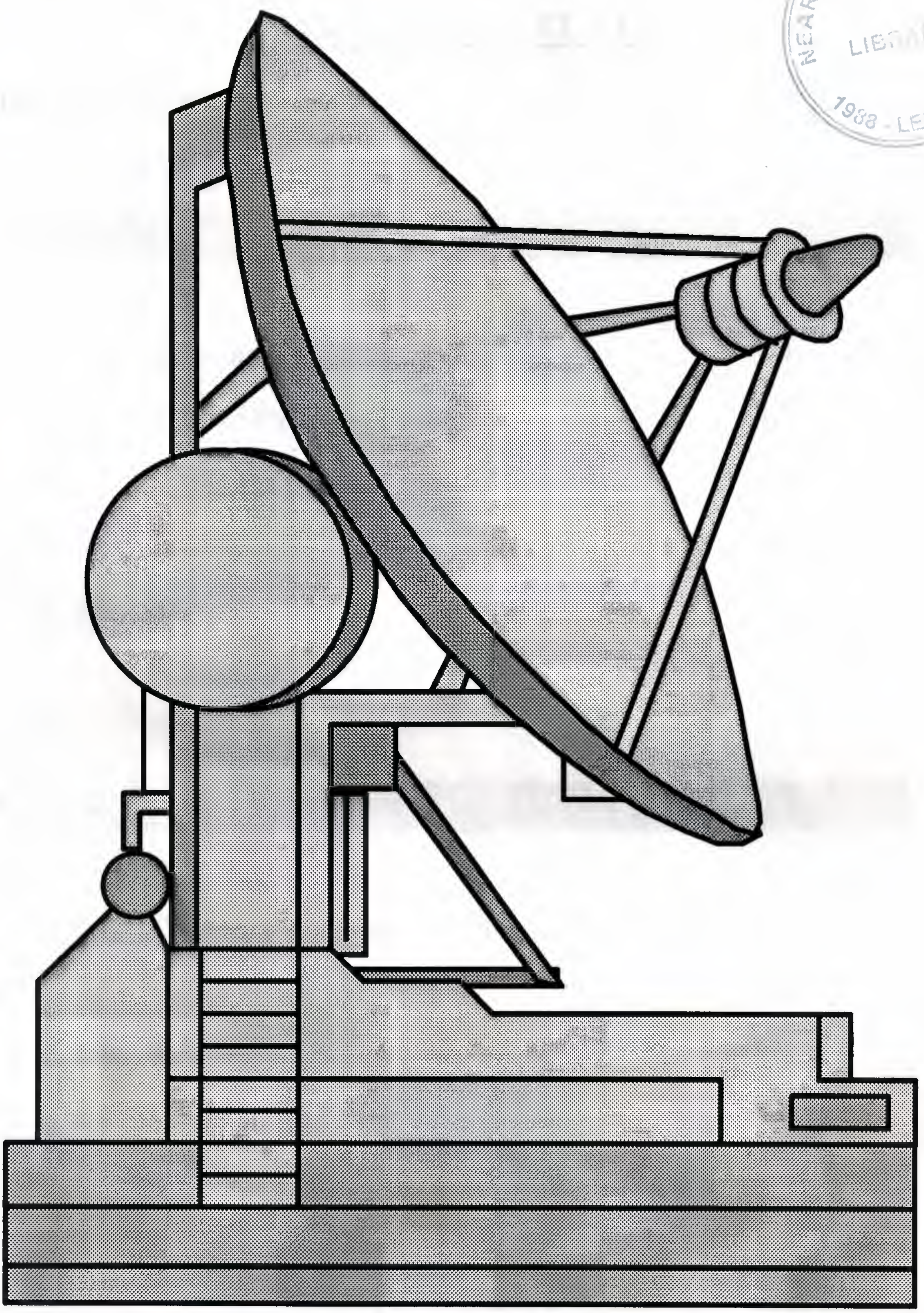

TABLE OF CONTENTS

INTRODUCTION 1-2

CHAPTER 1

1.1 Elements of Satellite Communication 3-4

1.2 Satellite Frequency Bands 4-7

1.3 Satellite Systems 7-9

1.4 Transmission 9-10

1.5 Reception 10-11

1.6 Modulation 11-13

CHAPTER 2

2.1 Communications Satellite, Orbit and Description 14

2.2 Orbital Period and Velocity 15-21

2.3 Adventages of Geostationary Orbit 21-22

2.4 Use of Inclined Orbit 22-23

2.5 Placement of a Satellite in a Geostationary Orbit 23-25

CHAPTER 3

3.1 Fundamentals of Spread Spectrum 26-27

3.2 Pseudo-Noise Sequence 27-29

3.3 Properties of Maximum-Lenght Sequences 29-32

3.4 Direct-Sequence Spread Consernt 32-33

3.5 Model for Analysis 33-34

3.6 Biphase Modulations 35

3.7 Quadriphase Modulation 36

3.8 A Notion of Spread Spectrum 37-40

CHAPTER 4

4.1 Frequency-Hop Spread Spectrum 41-42

4.2 Slow-Frequency Hopping (Transmitter) 42-43

4.3 Slow-Frequency Hopping (Receiver) 43-46

4.4 Fast-Frequency Hopping 46-47

CHAPTER 5

5.1	Time-Hopping	48-49
5.2	The Time Hopped Signal	49-50
5.3	Chirp Spread Spectrum	51
5.4	Comparision of Modulation Methods	51
5.5	Direct-equence (PN) Systems (Adventages and Disadventages)	51-52
5.6	Frequency-Hopping (FH) Systems (Adventsges and Disadventages)	52
5.7	Time-Hopping (TH) Systems (Adventages and Disadventages)	52-53
5.8	Hybird Spread-Spectrum Systems	53-54
5.9	Example of PN/FH System	54

CHAPTER 6

6.1 Application of Spread Spectrum to Communications 55-58

6.2 Examples of Spread Spectrum Systems 58-59

6.3 Code-Division Multiple Access 59-60

6.4 Summary and Discussion 60-63

CONCLUSION 64

REALIZATION OF PROJECT

APPENDIX A (FOR FIGURES)

REFERENCES AND BIBLIOGRAPHY

ABBREVIATIONS

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INTRODUCTION

Spread spectrum is not new. It was developed primarily by the military after world war II. Its use has been restricted to military communications applications because it is a secure communications techniques that is essentially immune to jamming. In the mid-1980's, the FCC authorised use of SS in civilian application.

Spread spectrum is a technique whereby an already modulated signal is modulated a second time in such a way as to produce a waveform which interferes in a barely noticeable way with any other signal (this type of modulation has been discussed in chap.3) operating in the same frequency band. Thus a receive tuned to receive specific AM or FM broadcast would probably not notice the presence of a spread spectrum signal operating over the same frequency band. Similarly, the receiving of the spread spectrum signal would not notice the presence of the AM or FM signal. Thus, we say that interfering signals are transparent to interfering signals. The different types of spread spectrum modulation techniques have been discussed in chap. 3, 4 and 5.

The widest application at this time is its use in military communications systems where spread spectrum serves two functions. The first is that it allows a transmitter to transmit a message to a receiving with not the message being detected by a receiving for which it is not intended. The second major application of spread spectrum is found, when, as a matter of fact, it turns out not to be possible to conceal the transmission.

In the commercial communications field spread spectrum has many applications, a major application being the transmission of a spread spectrum signal on the same carrier frequency as an already existing microwave signal. By communicating in this manner over additional signals can be transmitted over the same band thereby increasing the ≠ of users. The addition, spread spectrum is used in satellite communications and is being considered for use in local area networks.

CHAPTER 1

1.1. ELEMENTS OF SATELLITE COMMUNICATION

The unique feature of communications satellites is their ability to simultaneously link all users on the earth's surface, thereby providing distance insensitive point-to-multipoint communications. This capability applies to fixed terminals on earth and to mobile terminals on land, in the air, and at sea. Also, with satellites, capacity can be dynamically allocated to users who need it. These features make satellite communications systems unique in design. This chapter serves as an overview of satellite communication. A satellite with a circular equatorial orbit at a correct altitude of 35,786 km would make one revolution every 24 h: that is, it would rotate at the same angular velocity as the earth. And observer looking at such a geostationary satellite would see it hanging at a fixed spot in the sky. Clarke showed that three geostationary satellites powered by solar energy could provide world-wide communications for all possible types of services. Clarke's vision became a reality 20 years later when the International Telecommunications Satellite Organization (INTELSAT), established in 1964, launched the Early Bird (INTELSAT) in April 1965. Many INTELSAT satellites have been launched or are in the planning stages, ranging from instruments with a small capacity (240 voice circuits or one television channel) to those with a huge capacity (40,000 voice circuits for INTELSAT VI) and covering three regions-the Atlantic, Pacific, and Indian oceans. Fig.1.1.(See Appendix A).

Table 1.1. Electromagnetic frequency spectrum

Frequency	Wavelenght (m)	Designation
3 Hz - 30 kHz	10 - 10	Very low frequency (VLF)
30 - 300 kHz	10 - 10	Low frequency (LF)
300 kHz - 3 MHz	10 - 10	Medium frequency (MF)
3 - 30 MHz	10 - 10	High frequency (HF)
30 - 300 MHz	10 - 1	Very high frequency (VHF)
300 MHz - 3 GHz	1 -10	Ultrahigh frequency (UHF)
3 - 30 GHz	10 - 10	Superhigh frequency (SHF)
30 -300 GHz	10 - 10	Extremely high frequency (EHF)
10 - 10 GHz	3 x 10 - 3 x 10	Infrared, visible light, ultraviolet

1.2. SATELLITE FREQUENCY BANDS

Communications system employ the electromagnetic frequency spectrum shown in Table 1.1. The frequencies used for satellite communications are allocated in superhigh-frequency (SHF) and extremely high-frequency (EHF) band which are broken down into subbands as summarised in Table 1.2. Spectrum management is an important activity that facilitates the orderly use of the electromagnetic frequency spectrum not only for satellite communications but for other telecommunications applications as well. This done under the auspices of the International Telecommunications Union (ITU) which is a specialized agency of the United Nations (UN).

Table 1.2. Satellite Frequency Spectrum

Frequency Band	Range (GHz)
L	1 - 2
S	2 - 4
C	4 - 8
X	8 - 12
Ku	12 - 18
K	18 - 27
Ka	27 - 40
Millimetre	40 - 300

The frequency bans allocated by WARC-79 for satellite communications involve 17 service categories (although some of them represent special subcategorise), as listed in Table 1.3, and three geographic regions; region1 which includes Europe, Africa, the USSR, and Mongolia; region 2 which includes North an South America and Greenland; and region 3 which includes Asia (except the USSR and Mongolia), Australia, and Southwest Pacific. Tables 1.4 and 1.5 show the WARC-79 frequency allocations for fixed satellite services (FSS) and broadcasting satellite service (BSS).

Table 1.3. Satellite Services

Fixed	Meteorological
Intersatellite	Space operation
Mobile	Amateur
Land mobile	Radiodetermination
Maritime mobile	Radionavigation
Aeronautical mobile	Aeronautical radionavigation
Broadcasting	Maritime radionavigation
Earth exploration	Standard frequency and time signal
Space research	

Table 1.4. Frequency allocation for fixed satellite service

Frequency range (GHz)	Restrictions	Frequency range (GHz)	Restrictions
2.5 - 2.535	1n, 2d, 3d	18.1 - 21.2	d
2.535 - 2.655	1n, 2b, 3n	27 -27.5	1n, 2u, 3u
2.655 - 2.690	1n, 2b, 3u	27.5 - 31	u
3.4 - 4.2	d	37.5 - 40.5	d
4.5 - 4.8	d	42.5 - 43.5	u
5.725 - 5.85	1u, 2n, 3n	47.2 - 49.2	u
5.85 - 7.075	u	49.2 - 50.2	u
7.25 - 7.75	d	50.4 - 51.4	u
7.9 - 8.4	u	71 - 74	u
10.7 - 11.7	1b, 2d, 3d	74 - 75.5	u
11.7 - 12.3	1n, 2d, 3n	81 - 84	d
12.5 - 12.7	1b, 2n, 3d	92 - 95	u
12.7 - 12.75	1b, 2u, 3d	102 - 105	d
12.75 - 13.25	u	149 - 164	d
14 - 14.5	u	202 - 217	u
14.5 - 14.8	u	231 - 241	d
17.3 - 17.7	u	265 - 275	u
17.7 - 18.1	b		

1, Region 1; 2, Region 2; 3, Region 3; u, uplink (earth to space); d, downlink (space to earth); n, not allocated; b, bidirection.

Uplink limited to BSS feeder links.

Intended for but not limited to BSS feeder links.

Table 1.5. Frequency allocations for broadcasting satellite service

Frequency range (GHz)	Restriction
0.62 - 0.79	t
2.5 - 2.69	c
11.7 - 12.1	1, 3 only
12.1 - 12.2	
12.2 - 12.5	1, 2 only
12.5 - 12.7	2, 3c only
12.7 - 12.75	3c only
22.5 - 23	2, 3 only
40.5 - 42.5	
84 - 86	

t, Television only; c, community reception only; 1, region; 2, region 2; 3, region 3.

1.3. SATELLITE SYSTEMS

A satellite system consists basically of a satellite in space which links many earth stations on the ground, as shown schematically in Fig. 1.2. (See Appendix A).The user generates the based band signal which is routed to the earth station through the terrestrial network. The terrestrial network can be a telephone switch or a dedicated link to earth station. At the earth station the baseband signal is processed and transmitted by a modulated radio frequency (RF) carrier to the satellite. The satellite can be through of a large repeater in space. It receives the modulated RF carriers in its uplink (earth-to-space) frequency spectrum from all the earth stations in the network, amplifies these carriers, and retransmits them back to the earth in downlink (space-to-earth) frequency spectrum which is different from the uplink frequency spectrum in order to avoid interference. The receiving earth station processed the modulated RF carrier down the baseband signal which is sent through the terrestrial network to the user.

Most commercial communications satellites today utilize a 500-Mhz bandwidth on the uplink and a 500-Mhz bandwidth on the downlink. The most widely used frequency spectrum is the 6/4-Ghz band, with an uplink of 5.725 to 7.075 Ghz and a downlink of 3.4 to 4.8 Ghz. The 6/4-Ghz band for geostationary satellites is becoming overcrowded because it is also used by common carriers for terrestrial microwave links. Satellites are now being operated in the 14/12-Ghz band using an uplink of 12.75 to 14.8 Ghz and a downlink of either 10.7 to 12.3 Ghz or 12.5 to 12.7 Ghz . The 14/12-Ghz band will be used extensively in the future and is not yet congested, but one problem exists-rain, which attenuates 14/12-Ghz signals much more than it does those at 6/4 Ghz.

The typical 500-Mhz satellite bandwidth at the 6/4 and 14/12-Ghz bands can be segmented into many satellite transponder bandwidths. For example eight transponders can be provided, each with a nominal bandwidth of 54 MHz and a center-to-center frequency spacing of 61 MHz. Modern communications satellites also employ frequency reuse to increase the number of transponders in the 500 MHz allocated to them. Frequency reuse can be accomplished through orthogonal polarizations where one transponder operates in one polarization (e.g., vertical polarization) and a cross- polarized transponder operates in the orthogonal polarization (e.g., horizontal polarization).

We will now take a look at an earth station that transmits information to and receives information from a satellite. Figure 1.3(See Appendix A). shows the functional elements of a digital earth station. Digital information in the from of binary digits from the terrestrial network enters the transmit side of the earth station and is then processed (buffered, multiplexed, formatted, ect.) by the baseband equipment so that these forms of information can be sent to the appropriate destinations. The presence of noise and the nonideal nature of any communication channel introduce errors in the information being sent and thus limit the rate at which it can be transmitted between the source and the destination.

If the received information does not meet the error rate requirement, error-correction coding performed by the encoder can often be used to reduce the error rate to the acceptable level by inserting extra digits into the digital stream from the output of the baseband equipment. These extra digits carry no information but are used to accentuate the uniqueness of each information messages.

1.4. TRANSMISSION

In order to transmit to baseband digital information over a satellite channel that is a bandpass channel, it is necessary to transfer the digital information to a carrier wave at the appropriate bandpass channel frequency. This technique is called digital carrier modulation The function of the modulator is to accept the symbol stream from the encoder and use it to modulate and intermediate frequency (IF) carrier. In satellite communications the IF carrier frequency is chosen at 70 MHz for a communication channel using a 36-MHz transponder bandwidth and at 140 MHz for a channel using a transponder bandwidth of 54 or 72 MHz. A carrier wave at an intermediate frequency rather than at the satellite RF uplink frequency is chosen because it is difficult to design a modulator that works at the uplink frequency spectrum (6 or 14 Ghz, as discussed previously). For binary modulation schemes, each output digit from the encoder is used to select one of two possible waveforms. For M-ary modulation schemes the output of the encoder is segmented into sets of k digits, where M=2k and each digit set or symbol is used to select one of the M waveforms. For example, in one particular binary modulation scheme called phase-shift keying (PSK), the digit 1 is represented by the waveforms s1(t)= A cos w0t and the digit 0 is represented by the waveform s0(t)= - A cos w0t. where w0 is the intermediate frequency.

The modulated IF carrier from the modulator is fed to the upconverter, where its intermediate frequency w0 is translated to the uplink RF frequency, w_u in the uplink frequency spectrum of the satellite. This modulated RF carrier is then amplified by the high-power amplifier (HPA) to a suitable level for transmission to the satellite by the antenna.

1.5. RECEPTION

On the receive side the earth station antenna receives the low-level modulated RF carrier in the downlink frequency spectrum of the satellite. A low-noise amplifier (LNA) is used to amplify this low-level RF carrier requirement. The downconverter accepts the amplified RF carrier from the output of the low-noise amplifier and translates the downlink frequency w_d to the intermediate frequency w_o. The reason for downconverting the RF frequency of the received carrier wave to the intermediate frequency is that it is much easier to design the demodulator to work at 70 or 140 MHz than at a downlink frequency of 4 or 12 GHz. The modulated IF carrier is fed to the demodulator, where the information is extracted. The demodulator estimates which of the possible symbols was transmitted based on observation of the received IF carrier. The probability that a symbol will be correctly detected depends on the carrier-to-noise ratio of the modulated carrier, the characteristics of the satellite channel, and the detection scheme employed. The decoder performs a function opposite that of the encoder. Because the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and recover information-bearing digits. The information stream is fed to the baseband equipment for processing for delivery to the terrestrial network.

1.6. MODULATION

In digital modulation, the performance of the modulator is measured in terms of the average probability of bit error, or the bit error rate as it is often called. The binary information, which consists of sequences of 1 and 0 digits, can be used to modulate the phase, frequency, or amplitude, w_c is the carrier frequency, and ∅ is the carrier phase. To transmit the binary digit or bit 1, ∅ is set to 0 rad, and to transmit the bit 0, ∅ is set to π radians. Thus 1 is represented by the waveform A cos $w_c t$, and 0 is represented by the waveform A cos (wct + π) = - A cos wct. This type of discrete phase modulation is called phase-shift keying (PSK). Similarly, 1 can be transmitted by using the waveform A cos $w_1 t$ and 0 transmitted by using the waveform A cos $w_2 t$, where $w_1 \neq w_2$. This type of digital modulation is called frequency shift keying (FSK), where two waveforms at different carrier frequencies w1 and w2 are used to convey the binary information. The problem with digital modulation is that sometimes the binary digit 1 is transmitted but the demodulator decodes it as a 0, or vice versa, because of perturbation of the carrier by noise; this results in bit errors in the demodulations of the binary information. The average probability of the bit error P_b is a convenient measure of the performance of the demodulator and is a function of the ratio of the energy per bit E_b is the energy of the carrier during a signalling interval or bit duration T_b and $N_0/2$ is the noise power spectral density. When the baseband information is transmitted at a rate of R bits per second, the bit duration is simply $T_b = 1/R$ seconds, and this is also the signalling interval of the waveform that represents a particular bit. For example, in PSK modulation,

$$S_1(t) = A \cos w_c t \qquad 0 \leq t \leq T_b$$

$$S_2(t) = -A \cos w_c t \qquad 0 \leq t \leq T_b$$

where $S_1(t)$ represents 1 and $S_2(t)$ represents 0. By definition we have

$$E_b = \int S^2_1(t)\, dt = \int S^2_2(t)\, dt = \int A^2 \cos^2 w_c t\, dt$$

Note that $E_b \approx A^2 T_b/2$ when $W_c > 2\pi/T_b$. The quantity E_b/N_0 can be related to the average carrier power C, and the noise power N measured within the receiver noise bandwidth B. By definition, the average carrier power is

$$C = 1/T_b \int E[\, S^2(t)\,]\, dt$$

where $S(t)$ is the carrier waveform during the signalling interval T_b and

$E[\bullet]$ is the expected value. If all the carrier waveforms have identical energy E_b during any signalling interval, then

$$C = E_b / T_b$$

Recall that the power spectral density of noise is N0/2 and that the noise bandwidth is B. Hence the noise power measured within the noise bandwith for both positive and negative frequency is

$$N = N_oB$$

Therefore it is seen that the ratio of the energy per bit to the noise density can be expressed as

$$E_b/N_o = CT_b / (N/B) = T_bB\ (C/N)$$

where C/N is the average carrier-to-noise ratio. In satellite communications, it is the quantity C/N that is directly evaluated. Once the C/N is known and the bandwidth of the receiver is selected, Eb/N0 can be calculated, as well as the average probability of bit error P_b which is a function of E_b/N0.

CHAPTER 2

2.1. COMMUNICATIONS SATELLITE:

ORBIT AND DESCRIPTION

This chapter addresses the orbital mechanics of communications satellites, together with their construction, especially in relation to a geostationary satellite that appears to an observer on earth to be hanging perfectly still at one spot in the sky. But this is all relative-an observer in space sees a geostationary satellite orbiting the earth at a speed of 11,068.8 km/h. At this velocity the satellite makes one revolution around the earth in exactly the same amount of time its takes the earth to rotate once on its axis. Since the only great circle that is moving exactly parallel to the direction of the earth's rotation is the equator, the geostationary orbit lies in the equatorial plane at a distance of approximately 42,164 km from the earth's centre. A satellite that has a 24-h nonequatorial orbit is called a synchronous satellite.

Why use a geostationary satellite? Because it is stationary relative to a point on earth, there is no requirement for a tracking antenna and the cost of the space and earth segments is much less than for lower-altitude satellite systems. This is the principle advantage.

2.2. ORBITAL PERIOD AND VELOCITY

The motion of a satellite orbiting the earth can be described by Newton's laws of motion and the law of gravitation. Consider the earth as having a mass of M1 and the satellite a mass of M2 at distance R1 and R2 from some inertial origin as shown in Fig.2.1(See Appendix A). From Newton's second low of motion, which says that a force acting on a body is equal to the product of its mass and its acceleration, the forces F1 on the earth and F2 on the satellite are given by

$$F_1 = m_1 \; d^2 r_1 / dt^2$$

$$F_2 = m_2 \; d^2 r_2 / dt^2$$

Also according to Newton's law of gravitation, the attractive force between ant two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Thus

$$F_1 = - F_2 = g \; m_1 m_2 / r^2 \; (\mathbf{r} / r)$$

where g is the universal gravitational constant. From the above three equations we deduce that

$$d^2 \mathbf{r}_1 / dt^2 = g \, m_2 / r^2 \, (\mathbf{r}/r)$$

$$d^2 \mathbf{r}_2 / dt^2 = -g \; m_1 / r^2 \, (\mathbf{r}/r)$$

submitting $r = r_2 - r_1$ gives

$$d^2 \mathbf{r}/dt^2 = -g\ (m_1+m_2)\ \mathbf{r}/r^3$$

$$= -\mu\ \mathbf{r} / r^3 \qquad (2.1)$$

where $\mu = g\ (m1 + m2) \approx gm1$, since the mass of the satellite is negligible compared to that of the earth. The value gm1 is given in as $\mu \approx gm1 = 3.986013 \times 10^5\ km^3/S^2$. Equation (2.1) is known as the two body equation of motion in relative from. It describes the motion of a satellite orbiting the earth.

A satellite orbit is either elliptical or circular, as shown in Fig.2.2(See Appendix A), and its characteristics are governed by Kepler's laws:

First law: The orbit of a satellite is an ellipse with the centre of the earth at one focus.

Second law: The line joining the centre of the earth and the satellite sweeps over equal areas in equal time intervals.

Third law: The squares of the orbital periods of two satellites have the same ratio as the cubes of their mean distances from the centre of the earth.

In Fig:2.2(See Appendix A) the following notation is used:

r = distance of satellite from primary focus F which is the centre of the earth.

v = true anomaly, measured from primary focus F in the direction of motion from the perigee to the satellite position vector r.

a = semimajor axis of ellipse

b = semiminor axis of ellipse

e = eccentricity

Ea = eccentric anomaly defined by an auxiliary circle of radius a having the centre O of the ellipse as origin.

p = semiparameter

q = perigee distance, the point of the orbit closest to focus F

Q = apogee distance, the point of the orbit farthest from the focus F (not shown in Fig.2.2).

The first law is stated as the polar equation of the ellipse with origin at the primary focus. By using $p/e = r/e + r \cos v$, we have

$$p = r(1 + e \cos v) \qquad (2.2)$$

The second law, the law of areas, can be derived by finding the cross-product of the position vector r and the acceleration vector d^2r/dt^2 given by Newton's law in (2.1):

$$\mathbf{r} \times (d^2\mathbf{r}/dt^2) = \mathbf{r} \times (-\mu\ \mathbf{r}/r^3) \qquad (2.3)$$

With the help of the first law the integral of the above cross-product yields

$$\left| \mathbf{r} \times d\,\mathbf{r}/dt \right| = r^2\, dv/dt = \sqrt{\mu\, p} \qquad (2.4)$$

which means that the area swept out by the radial vector r in an infinitesimal time is constant. Rewriting the above equation and using the fact that $p = a(1 - e^2)$, as seen in Fig.2.2(See Appendix A), we have

$$r^2\, dv = \sqrt{\mu\, p}\, dt$$

$$= \sqrt{\mu a(1 - e2)}\, dt \qquad (2.5)$$

By using the relations

$$\cos v = (\cos E_a - e) / (1 - e \cos E_a) \qquad (2.6a)$$

and

$$\sin v = \sqrt{1 - e2}\, \sin Ea / (1 - e \cos Ea) \qquad (2.6b)$$

we obtain, by differentiating (2.6a),

$$-\sin v\, dv = dE_a / (1 - e \cos E_a)^2 [-\sin E_a (1 - e \cos E_a) - e \sin E_a (\cos E_a - e)]$$

and, with the substitution of (2.6b),

$$\sqrt{1 - e2}\, \sin E_a\, dv / (1 - e \cos E_a) = dE_a / (1 - e \cos E_a)^2 (1 - e^2) \sin E_a$$

$$dv = \sqrt{1 - e2}\; / (1 - e \cos E_a)\, dE_a$$

By using the relation r = a (1 - e cos Ea) and dv in the expression of r^2 dv in (2.5), we obtain

$$a^2 (1\text{-e} \cos Ea) \sqrt{1-e2}\ dEa = \sqrt{\mu a(1 - e2)}\ dt$$

or

$$(1\text{- e} \cos Ea)\ dEa = \sqrt{\mu}\ / a^{3/2}\ dt$$

The integral of this equation is called Kepler's equation:

$$M = Ea - e \sin Ea = \sqrt{\mu}\ / a^{3/2} (t - to) \qquad (2.7)$$

M is called the mean anomally and increases at a steady rate n, known as the mean angular motion:

$$n = \sqrt{\mu}\ / a^{3/2} \qquad (2.8)$$

To obtain the third law, the orbital period law, set Ea = 2π and T = t-t0 for the satellite period:

$$2\pi = \sqrt{\mu}\ / a^{3/2}\ T$$

or

$$T = 2\pi \ a^{3/2} \ / \ \sqrt{\mu} \qquad (2.9)$$

Note that the circular orbit is just a special case of the elliptical orbit where $a = b = r$.

To derive the orbital velocity of the satellite, we find the scalar product of the acceleration d^2r/dt^2 in (2.1) and dr/dt, obtaining

$$d\mathbf{r}/dt \bullet d^2\mathbf{r} \,/\, dt^2 = -\,\mu \,/\, r^3 \,(d\mathbf{r} \,/\, dt \bullet \mathbf{r}) \;=\; -\,\mu \;/\; r^2 (dr/dt)$$

The integral of this equation is

$$1/2 \,(d\mathbf{r}/dt \;\bullet\; d\mathbf{r}/dt) = 1/2\, \mathbf{v}^2 = \mu \,/r + C = 1/2[\,(dr/dt)^2 + (r \;\; dv/dt)^2]$$

where V is the velocity. At the perigee $dr/dt = 0$ and $r = q$, hence from (2.4)

$$r\, dv/dt = \sqrt{\mu \;\, p} \;\, /r = \sqrt{\mu \;\, p} \;\, /q$$

and

$$\mu \,/q + C = \mu p \,/2q^2$$

$$C = \mu/q \,(p/2q\text{-}1) = \mu/\, a(1\text{-}e)[\, a\, (1\text{-}e^2)/2a\, (1\text{-}e)\text{-}1]$$

$$= -\mu \,/\, 2a$$

Hence the orbital velocity is given by

$$V = \sqrt{\mu(2/a - 1/a)} \qquad (2.10)$$

The orbital period of the satellite is expressed in terms of mean solar time; it is not as accessible to measurement as another kind of time which is determined from the culminations of stars-siderial time. A sidereal day is defined as the time required for the earth to rotate once on axis relative to the stars.

A sidereal day is measured as 23 h, 56 min, and 4.09 s of mean solar time. A satellite with a circular orbital period of one sidereal day is called a synchronous satellite and has an orbit radius of

$$a = (T\sqrt{\mu} \;/ 2\pi)^{2/3} = 42{,}164.2 \text{ km}$$

If the synchronous orbit is over the equator and the satellite travels in the same direction as the earth's surface, the satellite will appear to be stationary over one point on earth. This type of orbit is over the equator and the satellite travels in the sane directions as the earth's surface, the satellite will appear to be stationary over one point on earth. This type of orbit is called a geostationary orbit. By taking the mean equatorial radius of the earth to be 6378.155 km , the distance from the satellite to the subsatellite point is found to be 42,164.2 - 6378.155 = 35,786.045 km for a geostationary orbit. (The subsatellite point is the point where the equator meets the line joining the centre of the earth and the satellite.)

The geostationary orbit is now employed for most commercial satellites because of the following advantages:

2.3. ADVANTAGES OF GEOSTATIONARY ORBIT

1. The satellite remains stationary with respect to one point on earth; therefore the earth station antenna is not required to track the satellite periodically. Instead, the earth station antenna beam can be accurately aimed toward the satellite by using the elevation angle and the azimuth angle (Fig.2.3) (See Appendix A). This reduces the station's cost considerably.

2. With a 5° minimum elevation angle of the earth station antenna, the geostationary satellite can cover almost 38% of the surface of the earth.

3. Three geostationary satellites (120° apart) can cover the entire surface of the earth with some overlapping, except for the polar regions above latitudes 76°N and 76°S, assuming a 5° minimum elevation angle.

4. The Doppler shift caused by a satellite drifting in orbit (because of the gravitational attraction of the moon and the sun) is small for all the earth stations within the geostationary satellite coverage. This is desirable for many synchronous digital systems.

2.4. USE OF INCLINED ORBIT

To cover the polar regions and to provide higher elevation angles for earth stations at high northern and southern latitudes, inclined orbits such as the one in Fig. 2.4(See Appendix A). can be used. The disadvantages of an inclined orbit are that the earth station antenna must acquire and track the satellite and the necessity for switching from a setting satellite to a rising satellite. This handover problem can be minimized by designing the orbit so that the satellite is over a certain region for a relatively long part of its period.

The satellite visibility for a station above 60° latitude with an antenna elevation greater than 20° is between 4.5 and 10.5 h.

Although geostationay satellite appears to be stationary in its orbit, the gravitational attraction of the moon and to a leser extend that of the sun cause it to drift from its stationary position and the satellite orbit tends to become inclined at a rate of about 1°/year. Also, nonuniformity of the earth's gravitational field and the radiation pressure of the sun cause the satellite to drift in longitude.

Stationkeeping is therefore required to maintain the position of a satellite accurately so that satellites in a geostationary orbit do not drift close together and cause adjacent satellite interference. North-south stationkeeping is required to prevent a drift in latitude, and east-west stationkeeping is needed to prevent a drift in longitude.

2.5. PLACEMENT OF A SATELLITE IN A GEOSTATIONARY ORBIT

The placement of a satellite in a geostationary orbit involves many complex sequences and is shown schematically in Fig.2.5(See Appendix A). First the launch vehicle (a rocket or a space shuttle) places the satellite in an elliptical transfer orbit whose apogee distance is equal to the radius of the geosynchronous orbit (42,164.2 km). The perigee distance of the elliptical transfer orbit is in general about 6678.2 km (about 300 km above the earth' surface). The satellite is than spin-stabilized in the transfer orbit so that the ground control can communicate with its telemetry system. When the orbit and attitude of the satellite have been determined exactly and when the satellite is at the apogee of the transfer orbit, the apogee kick motor is fried to circularized the orbit. This circular orbit, with a radius of 42,164.2 km, is a geostationary orbit if the launch is carried out at 0° latitude (i.e., at the equator).

The velocity at the perigee and apogee of the transfer orbit can be calculated from (2.10):

$$V = \sqrt{\mu(2/r - 1/e)}$$

At the perigee r = 6678.2 km, a =(6678.2 + 42,164.2)/2 = 24,402.2 km, and the velocity is

$$V_p = 10.15 \text{ km/s}$$

At the apogee r = 42,164.2 km, hence the velocity is

$$V_a = 1.61 \text{ km/s}$$

Since the velocity in asynchronous orbit (r = a = 42,164.2 km) is

$$V_c = 3.07 \text{ km/s}$$

the incremental velocity required to circularize the orbit at the apogee of the transfer orbit must be

$$\Delta V_c = V_c - V_a$$

$$= 3.07 - 1.61 = 1.46 \text{ km/s}$$

Satellites are now being placed in geostationary orbits by two major organizations: the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA). NASA uses a space transportation system (STS) or space shuttle to take the satellite to a circular parking orbit between 300 and 500 km with an inclination of 28°. The propulsion requirements for establishing the final geostationary orbit are satisfied by two impulsive manoeuvres. The first manoeuvre imparts a velocity increment of approximately 2.42 km/s for a 300-km parking orbit (in this orbit the satellite velocity is about 7.73 km/s, while the velocity at the perigee of the transfer orbit is 10.15 km/s) at the first equatorial crossing of the parking orbit. This establishes the elliptical transfer orbit with the perigee at the equatorial crossing where the maneuver has been described previously. ESA uses the Ariane rocket to carry the satellite directly to the elliptical transfer orbit. Since the transfer orbit established from the Ariane launch site in French Guiana is inclined only 5.3° to the geostationary orbit less fuel is required in the second maneuver for the Ariane launch. The Ariane is also capable of placing a satellite directly in a geostationary transfer orbit. NASA also uses the Atlas-Centaur and Delta rockets to compliment the space shuttle. Table 2.1 shows the space launchers available from various countries in the world.

Table 2.1 Space launchers for satellites

Launcher	Payload to geostationary orbit (thousands of pounds)	Payload to lower orbit, 100-500 miles (thousands of pounds)
United States		
Titan II		5,000
Titan III	10,000	
Titan IV	12,000	40,000
Delta 2	5,000	11,000
Atlas I	5,000	14,000
Atlas 2	6,000	
Shuttle		55,000
Europe		
Ariane 3	7,000	
Ariane 4	9,000	15,000
Ariane 5	16,000	44,000
USSR		
Vostok		11,000
Soyuz		17,000
Proton	8,000	43,000
Energia(withoutshuttle)		220,000
Energia(with shuttle)		66,000
China		
Long march 3	3,000	
Long march 2E	7,000	19,000
Japan		
H-2	9,000	18,000

CHAPTER 3

3.1. FUNDAMENTALS OF SPREAD SPECTRUM

For a communication system to be considered a spread-spectrum system, it is necessary that the transmitted signal satisfy two criteria. First the bandwidth of the transmitted signal must be much greater than the message bandwidth. This by itself however, is not sufficient because there are many modulation methods that achieve it. For example, frequency modulation, pulse code modulation, and delta modulation may have bandwidths that are much greater than the message bandwidth. Hence the second criterion is that the transmitted bandwidth must be determined by some function that is independent to the message and is known to the receiver. Methods of accomplishing this are discussed in a subsequent section.

The definition of spread spectrum may be stated in two parts.

1. Spread spectrum is a means of transmission in which the data of interest occupies a bandwidth in excess of the minimum bandwidth necessary to send the data.

2. The spectrum spreading is accomplished before transmission through the use of a code that is independent of the data sequence. The same code is used in the receiver (operating in synchronism with the transmitter) to despread the received signal so that the original data may be recovered.

Spread-spectrum modulation was originally developed for military applications where resistance to jamming (interference) is of major concern. However there are civilian applications that also benefit from the unique characteristics of spread- spectrum modulations. For example, it can be used to provide multipath rejection in a ground-based mobile ratio environment. Another application is in multiple-access communications in which a number of independent users are required to share a common channel without an external synchronizing mechanism; here, for example, we may mention a ground-based mobile radio envoirment involving mobile vehicles that communicate with a central station.

In this chapter, I discuss principles of spread-spectrum modulation, with emphasis on direct-sequence and frequency-hopping techniques. In a direct-sequence spread-spectrum technique, two stages of modulation are used. First, the incoming data sequence is used to modulate a wideband code. This code transforms the narrowband data sequence into a noise-like wideband signal, shift keying technique. in a frequency-hop spread spectrum technique, on the other hand, the spectrum of the data-modulated carrier is widened by changing the carrier frequency in a pseudo-random manner. For their operation, both of these techniques relay on the availability of a noise-like spreading code called a pseudo-random pseudo-noise sequence. Since such a sequence is basic to the operation of spread-spectrum modulation, it is logical that we begin our study by describing the generation and properties of pseudo-noise sequences.

3.2. PSEUDO-NOISE SEQUENCES

A pseudo-noise (PN) sequence is defined as a coded sequence of 1s and 0s with certain autocorrelation properties. The class of sequences used in spread-spectrum communications is usually periodic in that a sequence of 1s and 0s repeats itself exactly with a known period. The maximum-length sequence, represents a commonly used periodic (PN) sequence. Such sequences have long periods and require simple instrumentation in the form of a linear feedback shift register. Indeed, they possess the longest possible period for this method of generation. A shift register for length m consists of m flip-flops (two-state memory stages) regulated by a single timing clock. At each pulse of the clock, the state of each flip-flop is shifted to the next one down the line. In order to prevent the shift register from emptying by the end of m clock pulses, we use a logical (i.e., Boolean) function of the states of the m flip-flop to compute a feedback term, and apply it to the input of the first flip-flop. In a feedback shift register of the liner type the feedback function is obtained using modulo-2 addition of the outputs of the various flip-flops. This operation is illustrated in Fig.3.1(See Appendix A) for the case of m =3. Representing the states of the three flip-flops as x1, x2, and x3 the feedback function is equal to the modulo-2 sum of x1 and x3. A maximum length sequence so generated is always periodic with a period of

$$N = 2m - 1$$

where m is the length of the shift register (equivalent to the degree of the generator polynomial).

Consider the three-stage feedback shift register shown in Fig. 3.1(See Appendix A). It is assumed that the initial state of the shift register is 100 (reading the contents of the three flip-flops from left to right). Than the succession of states will be as follows:

100, 110, 111, 011, 101, 010, 001,100,.......

Table 3.1. Range of PN Sequence Lengths

Length of Shift Register, m	PN Sequence Length, N
7	127
8	255
9	511
10	1023
11	2047
12	4095
13	8191
17	131071
19	524287

The output sequence (the last position of the each state of the shift register) is therefore

0011101

which repeats itself with period 7.

3.3. PROPERTIES OF MAXIMUM-LENGTH SEQUENCES

Maximum length sequences have many of the properties possessed by a truly random binary sequence. A random binary sequence is a sequence in which the presence of a binary symbol 1 or 0 is equally probable. Some properties of maximum-length sequence are listed below:

Property 1

In each period of a maximum length sequence, the number of 1s is always one more than the number of 0s. The property is called the balance property.

Property 2

Among the runs of 1s and of 0s in each period of a maximum-length sequence, one-half the runs of each kind are of length one, one-fourth are of length two, one-eighth are of length three, so on as long as these fractions represent meaningful numbers of runs. This property is called the run property.

Buy a "run" we mean a subsequence of identical symbols (1s or 0s) within one period of the sequence. The length of this subsequence is the length of the run. For a maximum length sequence generated by a feedback shift register of length m, the total number of runs is $(m + 1)/2$.

Property 3

The autocorrelation function of a maximum length sequence is periodic and binary-valued. The property is called the correlation property.

Let binary symbols 0 and 1 be represented by -1 volt and +1 volt, respectively. By definition, the autocorrelation sequence of a binary sequence {Cn}, so represented, equals

$$Rc\,(k) = 1/N \sum CnCn\text{-}k \qquad (3.2.)$$

where N is the length or period of the sequence and k is the lag of the autocorrelation sequence. For a maximum-length sequence of length N, the autocorrelation sequence is periodic with period N and two valued as shown by,

$$Rc(k) = \begin{cases} 1 & k = lN \\ -1/N & k \neq lN \end{cases} \quad (3.3)$$

where l is any integer. When the length N is infinitely large, the autocorrelation sequence Rc(k) approaches that of a completely random binary sequence.

Consider again the maximum-length sequence generated by the feedback shift register of Fig 3.1(See Appendix A). The output sequence (represented in terms of binary symbols 0 and 1) is

$$\{Cn\} = \underbrace{0011101}_{N=7}\ldots \quad \text{E.q.3.4.}$$

In terms of the levels -1 and +1, the output sequence is

$$\{Cn\} = \underbrace{-1, -1, +1, +1, +1, -1, +1}_{N=7}\ldots\ldots \quad \text{E.q. 3.5.}$$

We see that there are three 0s (or -1's) and four 1s (or +1's) in one period of the sequence, which satisfies Property 1.

With N = 7, there are a total of four runs in one period of the sequence. Reading them from left to right in Eq.3.4, the four runs are 00,111,0, and 1. Two of the runs (a half of the total) are of length one, and one run (a quarter of the total) is of length two which satisfies Property 2.

Fig. 3.2a(See Appendix A) shows two full periods of the maximum-length sequence. Figure 3.2b(See Appendix A) shows the corresponding autocorrelation function Rc(τ) plotted as a function of the time lag τ. In this figure, the parameter Tc denotes the duration of binary symbol 1 or 0 in the sequence, and N is the length of one period of the sequence. The periodic and two-valued correlation property of the sequence is clearly seen in Fig.3.2b(See Appendix A).

3.4. DIRECT-SEQUENCE SPREAD COHERENT BINARY PHASE-SHIFT KEYING

The spread-spectrum technique for the use of this technique over a band-pass channel (e.g., satellite channel), we may incorporate coherent binary phase-shift keying (PSK) into the transmitter and receiver, as shown in Fig.3.5(See Appendix A). The transmitter of Fig.3.5a(See Appendix A) involves two stages of modulation. The first stage consists of a product modulator of multiplier with the data sequence and PN sequence as inputs. The second stage consists of a binary PSK modulator. The transmitted signal x(t) is thus a direct-sequence spread binary phase-shift-keyed (DS/BPSK) signal. The phase modulation θ(t) of x(t) has one of two values, 0 and π, depending of the polarities of the data sequence b(t) and PN sequence c(t) at time t in accordance with the truth table of Table 3.2. The receiver shown in Fig. 3.5b(See Appendix A), consists of two stages of demodulation. The received signal y(t) and a locally generated replica of the PN sequence are applied to a multiplier. This multiplication represents the first stage of demodulation in the receiver. The second stage of demodulation consists of a coherent detector, the output of which provides an estimate of the original data sequence.

Fig.3.4(See Appendix A). illustrates the waveforms for the first stage of modulation. Part of the modulated waveform shown in fig.3.4c(See Appendix A) is reproduced in fig.3.6a(See Appendix A), the waveform shown here corresponds to one period of the PN sequence. Fig.3.6b(See Appendix A) shows the waveform of a sinusoidal carrier, and fig 3.6c(See Appendix A) shows the DS/BPSK waveform that results from the second stage of modulation.

Table 3.2. Truth Table for Phase Modulation θ (t), **Radians**

		Polarity of Data Sequence b(t) at Time t	
		+	-
Polarity of PN sequence	+	0	π
c(t) at time t	-	π	0

3.5. MODEL FOR ANALYSIS

In the normal form the transmitter, shown in Fig. 3.5a(See Appendix A), the spectrum spreading is performed prior to phase modulation. For the purpose of analysis, however, we find it more convenient to interchange the other of these two operations, as in the model of Fig. 3.7(See Appendix A). We are permitted to do this because the spectrum spreading and the binary phase-shift keying are both linear operations. The model of Fig.3.7(See Appendix A) also includes representations of the channel and the receiver. In this model, it is assumed that the interference j(t) limits performance, so that the effect of channel noise may be ignored. Accordingly, the channel output is given by

$$y(t) = x(t) + j(t)$$

$$= c(t)\, s(t) + j(t)$$

where s(t) is the binary PSK signal, and c(t) is the PN sequence. In the receiver, the received signal y(t) is first multiplied by the PN sequence c(t) yielding an output that equals the coherent detector input u(t). Thus,

$$u(t) = c(t)\, y(t)$$

$$= c^2(t)\, s(t) + c(t)\, j(t)$$

$$= s(t) + c(t)\, j(t),$$

in the last line of Eq. 3.12, we have noted that, by design, the PN sequence c(t) satisfies the property described in Eq. 3.9, reproduced here for convenience:

$$c^2(t) = 1 \qquad \text{for all } t$$

Equation 3.12 shows that the coherent detector input u(t) consist of a binary PSK signal s(t) imbedded in additive code-modulated interference denoted by c(t)j(t). The modulated nature of the latter component force the interference signal (jammer) to spread is spectrum, such that the detection of information bits at the receiver output is afforded increased reliability.

3.6. BIPHASE MODULATION

A phase-modulated carrier can be expressed in general as

$$s(t) = A \sin [W_0 t + \varnothing(t)]$$

where A is the constant carrier amplitude and ∅(t) represent the phase modulation. In the case of biphase modulation, ∅(t) will be either zero or π. The values of ∅(t) for various combinations of the binary message, m(t), and the PN sequence, b(t) are shown in Table 3.3.

Table 3.3. Truth Table for ∅(t)

		m (t)	
		1	-1
b(t)	1	0	π
	-1	π	0

A block diagram of a system accomplishing biphase modulation is shown in Fig.3.8(See Appendix A). This system employs a balanced modulator that ideally produces the desired phase shift keying without any residual carrier at the output. It is necessary that the message bit duration t_m be an integral multiple of the chip duration t1 as shown in Fig.3.9(See Appendix A).

3.7. QUADRIPHASE MODULATION

A block diagram of a system producing quadriphase modulation is shown in Fig.3.10(See Appendix A). In this case two balanced modulators are used and the carriers to these two modulators are 90 degrees apart in phase. There are also two modulo-2 adders that at the message binary sequence to do so. This means that each chip of the PN code is stretched to a duration of 2t1 before being added to the binary message. The quadriphase signal can again be represented as

$$s(t) = A \sin [Wot + \varnothing(t)]$$

in which A is the carrier amplitude and $\varnothing(t)$ is the phase modulation. The relation of $\varnothing(t)$ to the state of the message and the states of the PN code sequence is shown in Table 3.4.

Table 3.4. Truth table for $\varnothing(t)$

		m (t)	
b1(t)	b2(t)	1	-1
1	1	π/4	5π/4
1	-1	7π/4	3π/4
-1	1	3π/4	7π/4
-1	-1	5π/4	π/4

It may be noted that the message modulation is still binary.

3.8. A NOTION OF SPREAD SPECTRUM

An important attribute of spread spectrum modulation is that it can provide protection against externally generated interfering (jamming) signals with finite power. The jamming signal may consist of a fairly powerful broadband noise or multitone waveform. That is directed at the receiver for the purpose of disrupting communication. Protection against jamming waveforms is provided by purposely making the information-bearing signal occupy a bandwidth far the excess of the minimum bandwidth necessary to transmit it. This has the effect of making the transmitted signal assume a noise-like appearance so as to bland into the background. The transmitted signal is thus enable to propagate through the channel undetected by anyone who may be listening. We may therefore think of spread spectrum as a method of "camouflaging" the information-bearing signal.

One method of widening the bandwidth of an information-bearing (data) sequence involves the use of modulation. Specifically, a data sequence b(t) is used to modulate a wide-band pseudo-noise (PN) sequence c(t) by applying these two sequences to a product modulator or multiplier, as in Fig.3.3a(See Appendix A). For this operation to work both sequences are represented in there polar forms that is, in terms of two levels equal in amplitude and opposite polarity (e.g., -1 and +1). We know from fourier transform theory that multiplication of two unrelated signals produces as a signal whose spectrum equals the convolution of a spectrum of the two component signal. Thus, if the data sequence b(t) is narrowband and the PN sequence c(t) is wideband the product signal m(t) will have spectrum that is nearly the same as the PN sequence. In other words, in the context of our present application, the PN sequence performs the role of a spreading code.

By multiplying the information-bearing signal b(t) by the spreading code c(t) each information bit is "chopped" up into a number of small time increments as illustrated in the waveforms of Fig.3.4(See Appendix A). The small time increment are commonly referred to as chips.

For baseband transmission, the product signal m(t) represents the transmitted signal. We may thus express the transmitted signal as

$$m(t) = c(t)\, b(t)$$

the received signal r(t) consist of the transmitted signal m(t) plus and additive interference denoted by i(t) as shown in the channel model of Fig.3.3.b(See Appendix A). Hence

$$\begin{aligned} r(t) &= m(t) + i(t) \\ &= c(t)\, b(t) + i(t) \end{aligned}$$

to recover the original data sequence b(t) the received signal r(t) is applied to a demodulator that consist of a multiplier followed by a low-pass filter as in Fig.3.3c(See Appendix A) the multiplier is supplied with a locally generated PN sequence that is an exact replica of that used in the transmitter. Moreover, we assume that the receive operates in perfect synchronism with the transmitter which means that the PN sequence in the receiver is lined up exactly with that in the transmitter. The resulting demodulated signal is therefore given by

$$z(t) = c(t)\, r(t)$$
$$= c^2(t)\, b(t) + c(t)\, i(t)$$

equation 3.8 shows that the desired signal b(t) is multiplied twice by the spreading code c(t) where as the unwanted signal i(t) is multiplied only once. The spreading code c(t) alternates between the levels -1 and +1, and the alternation is destroyed when is squared: Hence

$$c^2(t) = 1 \qquad \text{for all } t$$

accordingly, we may simplify Eq. 3.8.as

$$z(t) = b(t) + c(t)\, i(t)$$

we thus see form e.q., 3.10. that the data sequence b(t) is reproduce at the multiplier output in the receiver except for the effect of the interference represented by the additive term c(t) i(t). Multiplication of the interference i(t) by the locally generated PN sequence c(t) means that the spreading code will affect the interference just as it did the original signal at the transmitted. We now observe that the data component b(t) is narrowband, whereas the spurious component c(t) i(t) is wideband. Hence, by applying the multiplier output to a baseband (low-pass) filter with a bandwidth just large enough to accommodate the recovery of the data signal b(t) the spurious component c(t) i(t) is made narrowband, thereby removing most of its power. The effect of the interference i(t) is thus significantly reduce at the receiver output.

In summary, the use of spreading code (with pseudo-random properties) in the transmitter produces a wideband transmitted signal that appears noise-like to a receiver that has no knowledge of a spreading code we note that (for a prescribed data rate) the longer we made the period of the spreading code, the closer will the transmitted signal be to a truly random binary wave, and the harder it is to detect.

CHAPTER 4

4.1. FREQUENCY-HOP SPREAD SPECTRUM

In the type of spread spectrum systems discussed previously, the use of a PN sequence to modulate a phase-shift-keyed signal achieves instantaneous spreading of the transmission bandwidth. The ability of such a system to combat the effects of jammers is determined by the processing gain can be which is a function of the PN sequence length. The processing gain can be made larger by employing a PN sequence with narrow chip duration, which, in, turn, permits a great transmission bandwidth and more chips per bit. However the capabilities of physical devices used to generate the PN spread-spectrum signals impose a practical limit on the attainable processing gain. Indeed, it may turn out that the processing gain so attained is still not large enough to overcome the effects of some jammers of concern, in which case we have to resort to other methods. One such alternative method is to force the jammer to cover a wider spectrum by randomly hopping the data-modulated carrier for one frequency to the next. In effect the spectrum of the transmitted signal is spread sequentially rather that instantaneously; the term " sequentially" refers to the pseudo-random-ordered sequence of frequency hops.

The type of spread spectrum in which the carrier hops randomly from one frequency to another is called frequency-hop (FH) spread spectrum. A common modulation format for FH systems is that of M-ary frequency-shift keying (MFSK). The combination is referred to simply as FH/MFSK.

Two basic (technology-independent) characterizations of frequency hopping are:

1. Slow-frequency hopping, in which the symbol rate Rs of the MFSK signal is and integer multiple of the hop rate Rh. That is several symbols are transmitted on each frequency hop.

2. Fast-frequency hopping, in which the hop rate Rh is an integer multiple of the MFSK symbol rate Rs. That is, the carrier frequency will change to hope several times during the transmission of one symbol.

4.2. SLOW - FREQUENCY HOPPING TRANSMITTER

Figure 4.1a(See Appendix A) shows the block diagram of an FH/MFSK transmitter, which involves frequency modulation followed by mixing. First the incoming binary data are applied to an M-ary FSK modulator. The resulting modulated wave and the output from a digital frequency synthesizer are then applied to a mixer that consists of a multiplier followed by a filter. The filter is designed to select the sum frequency component resulting from the multiplication process the transmitted signal. In particular, successive (not necessarily disjoint) k-bit segments of a PN sequence drive the frequency synthesizer, which enables the carrier frequency hop over 2k distinct values. One a single hop the bandwidth of the transmitted signal is the same as that resulting from the use of a conventional M-ary frequency-shift-keying (MFSK) format with an alphabet of M = 2k orthogonal signals. However, for a complete range of 2k-frequency hops, the transmitted FH/MFSK signal occupies a much larger bandwidth. Indeed , with present-day technology, FH bandwidth of the order of several GHz are attainable which is an order of magnitude larger than that achievable with direct-sequence spread spectra. An implication of these large FH bandwidths is that coherent detection is possible only within each hop, because frequency synthesizers are unable to maintain phase coherence over successive hops. Accordingly, most frequency-hop spread- spectrum communication systems use noncoherent M-ary modulation schemes.

4.3. RECEIVER

In the receiver depicted in Fig.4.1b(See Appendix A), the frequency hopping is first removed by mixing (down-converting) the received signal with the output of a local frequency synthesizer that is synchronously controlled in the same manner as that in the transmitter. The resulting output is then band-pass filtered, and subsequently processed by a noncoherent M-ary FSK detector. To implement this M-ary detector, we may use a bank of M noncoherent matched filters, each of which is matched to one of the MFSK tones. An estimate of the original symbol transmitted is obtained by selecting the largest filter output.

An individual FH/MFSK tone the shortest duration is referred to as a chip;

The chip rate, Rc, for an FH/MFSK is defined by

$$Rc = \max\ (Rh,Rs)$$

where Rh is the hope rate, and Rs is the symbol rate.

A slow FH/MFSK signal is characterized by having multiple symbols transmitted per hop. Hence , each symbol a slow FH/MFSK signal is a chip. Correspondingly, in a slow FH/MFSK system the bit rate

R_b of the incoming binary data, the symbol rate R_s of the MFSK symbol the chip rate R_c, and the hop rate R_h are related by

$$R_c = R_s = R_b / K \geq R_h$$

where $K = \log_2 M$.

Figure 4.2a(See Appendix A) illustrates the variation of the frequency of a slow FH/MFSK signal with time for one complete period of the PN sequence. The period of the Pn sequence is $(2^2)^2 - 1 = 15$. The FH/MFSK has following parameters:

Number of bits per MFSK symbol	K = 2
Number of MFSK tones	M = 2k = 4
Length of PN segment per hop	k = 3
Total number of frequency hops	2k = 8

In this example, the carrier is hopped to a frequency after transmitting two symbols or equivalently, four information bits. Fig.4.2a(See Appendix A) also includes the input binary data, and the PN sequence controlling the selection of FH carrier frequency. It is noteworthy that although there are eight district frequencies available for hopping, only three of them are utilized by the Pn sequence.

Figure 4.2b(See Appendix A) shows the variation of the developed frequency with time. This variation is recognized to be the same as that of a conventional MFSK signal produced by the given input data.

At each hop, the MFSK tones are separated in frequency by an integer multiple of the chip rate Rc = Rs, ensuring their orthogonality. The implication of this condition is that any transmitted symbol will not produce any crosstalk in the other M - 1 noncoherent matched filters constituting the MFSK detector of the receiver in Fig.4.1b(See Appendix A); By " crosstalk" we mean the spillover from one filter output into and adjacent one. The resulting performance of the slow FH/MFSK system is the same as that for the noncoherent detection of conventional (unhopped) MFSK signals in additive white Gaussian noise (AWGN). Thus the interfering (jamming) signal has an effect on the FH/MFSK receiver, in terms of average probability of symbol error, equivalent to that of additive white Gaussian noise on a conventional noncoherent M-ary FSK receiver experiencing no interference.

Assuming that the jammer decides to spread its average power J over the entire frequency-hopped spectrum, the jammer's effect is equivalent to an AWGN with power spectral density No/2, where $N_0 = J/W_c$ and W_c is the FH bandwidth. The spread-spectrum system is thus characterised by the symbol energy-to-noise density ratio:

$$E/N_0 = (P/J) / (W_c / R_s)$$

where the ratio P/J is the reciprocal of the jamming margin. The other ratio is the processing gain of the slow FH/MFSK system defined by

$$\begin{aligned} PG &= W_c / R_s \\ &= 2k \end{aligned}$$

That is, the processing gain (expressed in decibels) is equal to

10 $\log_{10} 2^k = 3k$, where k is the length of the PN segment employed to select a frequency hop.

This result assumes that the jammer spreads its power over the entire FH spectrum. However, if the jammer decides to concentrate on just a few of the hopped frequencies, then the processing gain realized by the receiver would be less than 3k decibels.

4.4. FAST FREQUENCY HOPPING

A fast FH/MFSK system differs from a slow FH/MFSK system in that there are multiple hops per M-ary symbol. Hence, in a fast FH/MFSK system, each hop is a chip. In general fast-frequency hopping is used to defeat a smart jammer's tactic that involves two functions: measurement of the spectral content of the transmitted signal, and retuning of the interfering signal to that portion of the frequency band. Clearly, to overcome the jammer, the transmitted signal must be hopped to a new carrier frequency before the jammer is able to complete the processing of these two functions.

Figure.4.3a(See Appendix A) illustrates the variation of the transmitted frequency of a fast FH/MFSK signal with time. The signal has the following parameters:

Number of bits per MFSK symbol	K = 2
Number of MFSK tones	M = 2k = 4
Length of PN segment per hop	k = 3
Total number of frequency hops	2k = 8

In this example, each MFSK symbol has the same number of bits and chips; that is the chip rate Rc is the same as the bit rate Rb. After each chip, the carrier frequency of the transmitted MFSK signal is hopped two different value, except for few occasions when the k-chip segment of the PN sequence repeats itself.

Figure 4.3b(See Appendix A) depicts the time variation of the frequency of the dehopped MFSK signal.

For data recovery at the receiver, noncoherent detection is used. However the detection procedure is quite different from that used in a slow FH/MFSK receiver. In particular, two procedures may be considered:

1. For each FH/MFSK separate decisions are made on the K frequency-hop chips received, and a simple rule based on majority vote is used to make an estimate of the dehopped MFSK symbol.

2. For each FH/MFSK symbol, likelihood functions are computed as functions of the total signal received over chips, and the larger one is selected.

A receiver based on the second procedure is optimum in the sense that it minimizes the average probability of symbol error for a given Eb/No.

CHAPTER 5

5.1. TIME HOPPING

A time-hopping waveform is illustrated in Fig 5.1(See Appendix A). The time axis is divided into intervals known as a frames, and each frame is subdivided into M time slots. During each frame one and only one time slot will be modulated with a message by any reasonable modulation method. The particular time slot that is chosen for a given frame is selected means of a PN code generator. All of the message bits accumulated in the previous frame are transmitted in a burst during the selected time slot. To quantify this concept, let

T_f = frame duration

K = number of message bits in one frame

$T_f = kt_m$

The width of each time slot in frame is T_f/M and the width of each bit in the time slot is T_f/kM, which is simply t_m/M. This indicates that the transmitted signal bandwidth is 2M times the message bandwidth, and hence the processing gain of a time-hopping system is simply twice the number of time slots in each frame when biphase modulation is used, and half this when quadriphase modulation is used.

A typical time-hopping receiver is shown in Fig. 5.2(See Appendix A). It consists of an on-off switch that is driven by a PN code generator in order to do the switching at the proper time in each frame. The output of this switch is then demodulated by either a two-phase or four-phase demodulator, depending on the nature of the transmitted signal. Bit synchronization is also required and the output of the bit synchronizer is used to control the clock that drives the PN code generator to maintain synchronization. Since the message bits are coming out a much greater rate than that at which the were originally produced, each burst must be stored and then retimed to the normal message rate. Time hopping is most often used in conjunction with other spread-spectrum techniques.

Interference among simultaneous users in a time-hopping system can be minimized by coordinating the times at which each user can transmit a signal. This also avoids the near-far problem. In a noncoordinated system, overlapping transmission bursts will result in message errors , and this will normally require the use of error- correction coding to restore the proper message bits. The acquisition time is similar to that of direct-sequence system for a given bandwidth. Implementation is simpler than that of a frequency-hop system.

5.2. THE TIME-HOPPED SIGNAL

A typical time-hopped signal is represented in Fig. 5.3(See Appendix A). The duration of each frame is T_f seconds and each frame there is one transmission burst that will contain k message bits. If there are M such burst periods in each frame, then the width of each burst is T_f/M and the frame duration must be

$$T_f = kt_m$$

Since these are transmitted in T_f/M seconds, the duration of each chip within a burst must be

$t_1 = Tf / kM$ biphase modulation

$= 2Tf / kM$ quadriphase modulation

Note that this result depends upon whether biphase modulation or quadriphase modulation is used.

Sine the bandwidth of the transmitted signal is equal to

$$B_s = 2 / t_1$$

this becomes, $B_s = 2kM / Tf$ biphase

$= kM / Tf$ quadriphase

Again this depends upon whether biphase or quadriphase modulation is used.

The processing gain of the time-hopped signal is the ratio of the signal band-width to the message bandwidth and becomes

$$PG = B_s / B_m = (2kM / Tf) / (1 / t_m) = 2M \quad \text{biphase}$$

$$= (kM / Tf) / (1 / t_m) = M \quad \text{quadriphase}$$

For a given processing gain, the interference rejection and the jamming margin are not be same for direct-sequence systems. Also the evaluation of intercept energy may be quite different, because the energy is concentrated in such a small time interval. Because of this small time interval, the transmitted power is large during this time and hence signals may be detected on a single-hop basis that could not be detected if they used the same energy as a direct-sequence system.

5.3. CHIRP SPREAD SPECTRUM

A chirp spread- spectrum system utilized linear frequency modulation of the carrier to spread the bandwidth. This is a technique that is very common in radar systems, but is also used in communication systems. The relationships between frequency and time are shown in Fig 5.4(See Appendix A), in which T is the duration of a given signal waveform and B bandwidth over which the frequency is varied. In this case the processing gain is simply BT. It is also possible to use nonlinear frequency modulation, and in some cases this may be desirable.

5.4. COMPARISON OF MODULATION METHODS

It is desirable at this point to include a list of the advantages and disadvantages of the three types of spread-spectrum systems that have been discussed so far. The purpose of this comparison is to illustrate that each method has its advantages and disadvantages, and that it may be possible to overcome some of these this advantages by the use of a combination of techniques. The advantages and disadvantages of the various systems are outlined below.

5.5. DIRECT-SEQUENCE (PN) SYSTEMS

<u>Advantages</u>

* Best noise and antijam performance.

* Most difficult to detect.

* Best discrimination against multipath.

Disadvantages

* Requires wide-band channel with little phase distortion.

* Long acquisition time.

* Fast code generator needed.

* Near-far problem.

5.6. FREQUENCY-HOPPING (FH) SYSTEMS

Advantages

* Greatest amount of spreading.

* Can be programmed to avoid portions of the spectrum.

* Relatively short acquisition time.

* Less affected by near-far problem.

Disadvantages

* Complex frequency synthesizer.

* Not useful for range and range-rate measurement.

* Error correction required.

5.7. TIME-HOPPING (TH) SYSTEMS

Advantages

* High bandwidth efficiency.

* Implementation simpler than FH.

* Useful when transmitter is average power limited but not peak power limited.

* Near-far problem avoided in a coordinated system.

Disadvantages

* Long acquisition time.

* Error correction needed.

5.8. HYBRID SPREAD-SPECTRUM SYSTEMS

The use of the hybrid system attempts to capitalize upon the advantage of a particular method while avoiding the disadvantages. Many different hybrid combinations are possible. Some of these are

PN/FH

PN/TH

FH/TH

PN/FH/TH

To illustrate how a hybrid system might operate, consider of the case of a PN/FH hybrid system. This system might use a PN code spread the signal to an extent limited by either code generator speed or acquisition time. When frequency hopping would be used to increase the frequency spread. The difference between the frequencies in the frequency-hopping portion of the system would normally be equal to the bandwidth of the PN code modulation. Usually some from of noncoherent message modulation is used because of the frequency hopping, and differential phase shift keying is a typical example. Since there are fewer frequencies to be implemented, the frequency synthesizer is similar for a given overall bandwidth. Thus this system gains some of the advantages of direct sequence systems and of frequency-hop systems, and avoids some of the disadvantages of both. A typical example of a PN/FH system is shown in the following.

5.9. EXAMPLE OF PN/FH SYSTEM

* PN rate of 250,000 chips per second.

* FH spreading to 2.048 Ghz (8192 frequencies separated by 250 KHz).

* Error correction from the third rate convolutional coding.

* Message rate: 75 b/s or 2400 b/s.

* PG = 74.3 dB at 75b/s = 59.2 dB at 2400 b/s.

CHAPTER 6

6.1. APPLICATION OF SPREAD SPECTRUM TO COMMUNICATIONS

There are many possible applications and only a few are presented here. One of the most important applications is usually referred to as multiple access arises when a number of independent users are required to convey their messages through a common facility. An outstanding example of this is the satellite communication system in which all messages from ground stations mast pass through a common satellite repeater. Another such application is ground-based mobile communications in which mobile vehicles must communicate with a central base station.

The classical method of providing multiple-access capability is frequency division(FDMA). In frequency division each user is assigned a particular frequency channels are occupied the system has reached its capacity and a further users may be accommodate.

A more recent technique for providing multiple access is time-division multiple access (TDMA). In time-division multiple access, each user is assigned particular time slot within a time frame, and during this time slot, transmits a portion of a message by any standard digital technique. Time division multiple access is an important application for satellite communications as well as ground-based digital communication systems. Again, however, when all time slots are occupied the system is operating at capacity and no additional users can be accommodate.

This third general class of multiple-access communication systems is usually referred to as code-division multiple access (CDMA). Code-division multiple access is always accomplished by means of spread spectrum. In this system each user is assigned a particular code, that is , either a particular PN sequence or a particular frequency-hopping pattern. It is the fact that each user has a unique code that enable the messages to be separated at the receiving point.

An additional advantage of CDMA is that the messages intended for one user are not readily decodable by other users, because they may not know the proper codes or have the equipment for the generating the appropriate reference signals. Thus there is a privacy feature that is not available in other multiple access techniques. An important consideration in CDMA is the number of users that can be accommodated simultaneously.

A second application of spread spectrum is usually referred to as selective calling. In a sense selective calling is the inverse of multiple access, that is, there is a central station that must communicate with a number of different receiving points and it wishes to do so on a selective basis. The message is intended for one receiving point and should not be received points. This is accomplished by having distinct codes assigned to each receiving point. An example of such a system might be ground-based radio system in which there is a central station that this communicating with a number of mobile receivers.

Another application of spread spectrum arises from its ability to resist the effects of international jamming. This antijam capability was in fact the primary reason for early consideration of spread spectrum communications by the military.

An application of spread spectrum that is also of interests to the military is that of covert communication or low probability of intercept. In this case it is desired to maintain in signal spectral density that is sufficiently small that its presence is not readily detected or that it cannot be detected on a chip-by-chip basis.

A characteristic of spread spectrum that is particular interest in mobile communications is the ability of a wide-band signal to resist the effect of multipath fading. A property of multipath fading is that frequencies separated by only a few hundred KHz. may fade essentially independently. Thus at any given time when the signal has a large bandwidth, only a small potion of the bandwidth will be in a fade. The average received signal power thus can be made more nearly constant than it would be for a narrow-band signal. This resistance to fading is a important consideration in the potential application of spread spectrum to mobile communication situations.

A sixth reason for using spread spectrum lies in it is ability to accommodate a secure communication system. If code are made sufficiently complex, it becomes very difficult to break them, and for unauthorised listeners to determined what the message actually is. This secrecy capability is important not only to the military, but in many commercial applications.

A final application of spread spectrum lies in it is ability to yield accurate distance information. It is well known that a broadband signal can be result in time much more precisely than a narrow-band signal. Thus by transmitting a signal with a large bandwidth, it is possible to measure delay times much more accurately and obtain more accurate range information. This is of importance rub only in radar system, but also in navigation system. Thus there are many spread spectrum radars that are intended for high-resolution target detection, and there are several electronic navigation system in coorporating spread spectrum signals.

6.2. EXAMPLES OF SPREAD - SPECTRUM SYSTEMS

The purpose of this section is provide a very brief description of certain spread-spectrum systems that are either in operation or in the planning phase at the present time.

One example of the direct-sequence system is the satellite navigation system known as the Global Positioning System (GPS). This system employs spread spectrum for the purposes: One purpose is to accommodate the multiple-access capability, since each user of the system must receive signals from four different satellites in order to make proper measurements of the user's position. These signals arriving constantly, so it is necessary that the user be able to distinguish among them. Therefore, distinct codes are assigned to the various satellites so that users can tell which signals they are receiving. The second reason is to increase the resolution capability so that the accuracy of the system is improved. For this purpose there is a PN sequence running at a chip rate of 10.23 megachips per second and modulated with data at a rate of 50 b/s. This leads to a processing gain of about 56 dB an enables the system to operate with input signal-to-noise rations of the order of -34 dB.

Another direct-sequence system is the Telecommunication Data Relay Satellite System (TDRSS), which relays data to and from the space shuttle. In this case spread spectrum is used primarily to reduce the energy density of the radiation at the surface of the earth in order to meet CCIR requirements. The S-band portion of the system utilizes a PN code running at 11.232 megachips per second with a code period of 2047 chips. This is modulated by data either at 32kb/s. or 216kb/s. Thus the processing gain is not extremely high, but this was not the original objective of using spread spectrum.

An example of a frequency-hopping system that is being developed is SINCGRAS. This system operates in the 30-to 88- MHz band and utilizes a very long hopping sequence with hop frequencies separated by 25 kHz. The hop rate is quite low and each hop is modulated with binary FM. Special features are incorporated to make it possible to reduce the acquisition time to a small enough value that push-to-talk operation is possible.

6.3. CODE-DIVISION MULTIPLE ACCESS

Code-division multiple Access is explained here as an example of application of SS-System. The two most common multiple access techniques for satellite communication are frequency-division multiple access (FDMA) and time-division multiple access (TDMA). In FDMA, all users access the satellite channel by transmitting simultaneously but using this joint frequency bands. In TDMA, all users occupy the same RF bandwidth of the satellite channel by the transmit sequentially in time. When, however, all users are permitted to transmit simultaneously and also occupy the same RF bandwidth of the satellite channel, then some other method must be provided for separating the individual signals at the receiver. Code division multiple access (CDMA) is the method that makes it possible to perform this separation.

To accomplish CDMA, spread spectrum is always used. In particular, each user is assigned a code of its own, which performs the direct-sequence or frequency-hop spread-spectrum modulation. The design of the codes has to cater for two provisions:

1. Each codes approximately orthogonal (i.e., has low cross-correlation) with all the other codes.

2. The CDMA system operates asynchronously, which means that the transition times of a user's data symbols do not have to coincide with those of the other users.

The second requirement complicates the design of good codes for CDMA. The use of CDMA offers three attractive features over TDMA.

1. CDMA does not require an external synchronization network, which is an essential feature of TDMA.

2. CDMA offers gradual degradation in performance as the number of users increased. It is therefore relatively easy to add new users to the system.

3. CDMA offers an external interference rejection capability (e.g., multipath rejection or resistance to deliberate jamming).

6.4. SUMMARY AND DISCUSSION

Direct-sequence M-ary phase shift keying (DS/MPSK) and frequency-hop M-ary frequency shift keying (FH/MPSK) represent to principle categories of spread spectrum communication. Both of them rely on the use of a pseudo-noise (PN) sequence, which is applied differently in the two categories.

In a DS/MPSK system, the PN sequence makes the transmitted signal assume a noise-like appearance by spreading its spectrum over a board range of frequencies simultaneously. For the phase-shift keying, we may use binary PSK (i.e., M = 2) with a single carrier. Alternatively, we may use QPSK (i.e.,M = 4),in which case the data are transmitted using a pair of carriers in phase quadrature. In spread spectrum system, bandwidth efficiency is usually note of prime concern.

In an FH/MFSK system, the PN sequence makes the carrier hop over a number of frequencies in a pseudo-random manner, with the measure that the spectrum of the transmitted signal is spread in a sequential manner.

Naturally, the direct-sequence and frequency-hop spectrum-spreading techniques may be employed in a single system. The resolution system is the referred to as a hybrid DS/FH spread-spectrum system. The reason for seeking a hybrid approach is that advantage of both the directs-sequence and frequency-hop spectrum-spreading techniques are realized in the same system. Indeed the hybrid approach is the only practical way of realising extremely wide-spectrum spreading.

For its proper operation, spread-spectrum communication requires that the locally generated PN sequence use in the receiver to despread the received signal be synchronized to the PN sequence use to the transmitted signal in the transmitter. A solution to the synchronized problem consists of two parts: acquisition and tracking. In acquisition or coarse synchronization, the two PN codes are aligned to within a fraction of a chip in as short a time as possible. Once the incoming PN code has been acquired, tracking, or fine synchronization, takes place. Typically, PN acquisition proceeds in two steps. First, the received signal is multiplied by a locally generated PN code produce a measure of correlation between it and the PN code used in the transmitter. Next, an appropriate decision-rule and search strategy is used to process the measures of correlation so obtains to determine whether the two codes are in synchronism and what to do if they are not. As for tracking, it is accomplished using phase-lock techniques very similar to those used for the local generation of coherent carrier references. The principle difference between them lies in the way in which phase discrimination is implemented.

A discussion of spread-spectrum communications would be incomplete without some reference to jammer waveforms. The jammers encountered in practice include the following types.

1. The barrage jammer, which consists of band-limited white Gaussian noise of high average power. The barrage noise jammer is a brute-force jammer that does not exploit any knowledge of the antijam communication system except for its spread bandwidth.

2. The partial-band noise jammer, which consists of noise whose total power is evenly spread over some frequency band that is a subset of the total spread bandwidth. Owing to the smaller bandwidth, the partial-band noise jammer is easier to generate than the barrage noise jummer.

3. The pulsed noise jammer which involves transmitting wideband noise of power

$$J_{peak} = J/p$$

for a fraction p of the time, and nothing for the remaining fraction 1-p of the time. The average noise power equals **J**.

4. The single-tone jammer, which consists of a sinusoidal wave whose frequency lies inside the spread bandwidth. A such, it is the easiest of all jamming signals to generate.

5. The multitone jammer, which is the tone equivalent of the partial-band noise jammer.

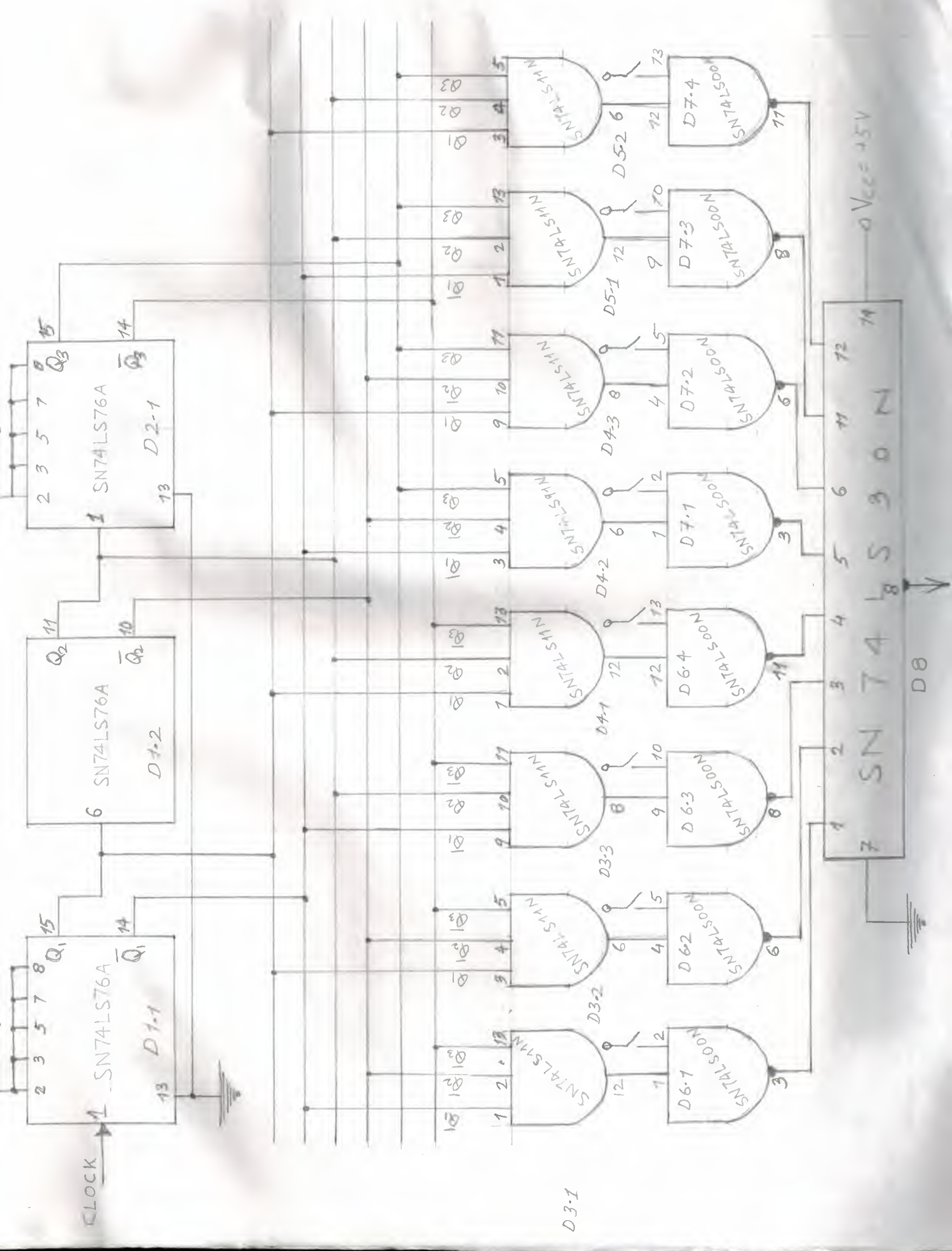
The pulsed-noised jammer is particularly effective against DS/BPSK systems. Correspondingly partial-band noise and multitone jammers a most effective against FH/MFSK system. Those jamming strategies are effective because they are able to concentrate jamming resources on some fraction of the transmitted symbols, thereby resulting bursts of errors at the receiver output. To deal with this problem, a spread-spectrum system will rely on very powerful error-correcting codes combined with interleaving. Specifically in the transmitter, the incoming data are first encoded, interleaved, and than applied to a spread-spectrum modulator. In the receiver, the received signal is despread, demodulated, deinterleaved, and then detected. Indeed, than error correcting codes and interleaving are combined with hybrid DS/FH spread spectrum (i.e., pseudo-random chipping and pseudo-random frequency hopping), the result is a digital communication system that can provide very significant projection against external noise, unintentional interference, and intentional jamming.

REALIZATION

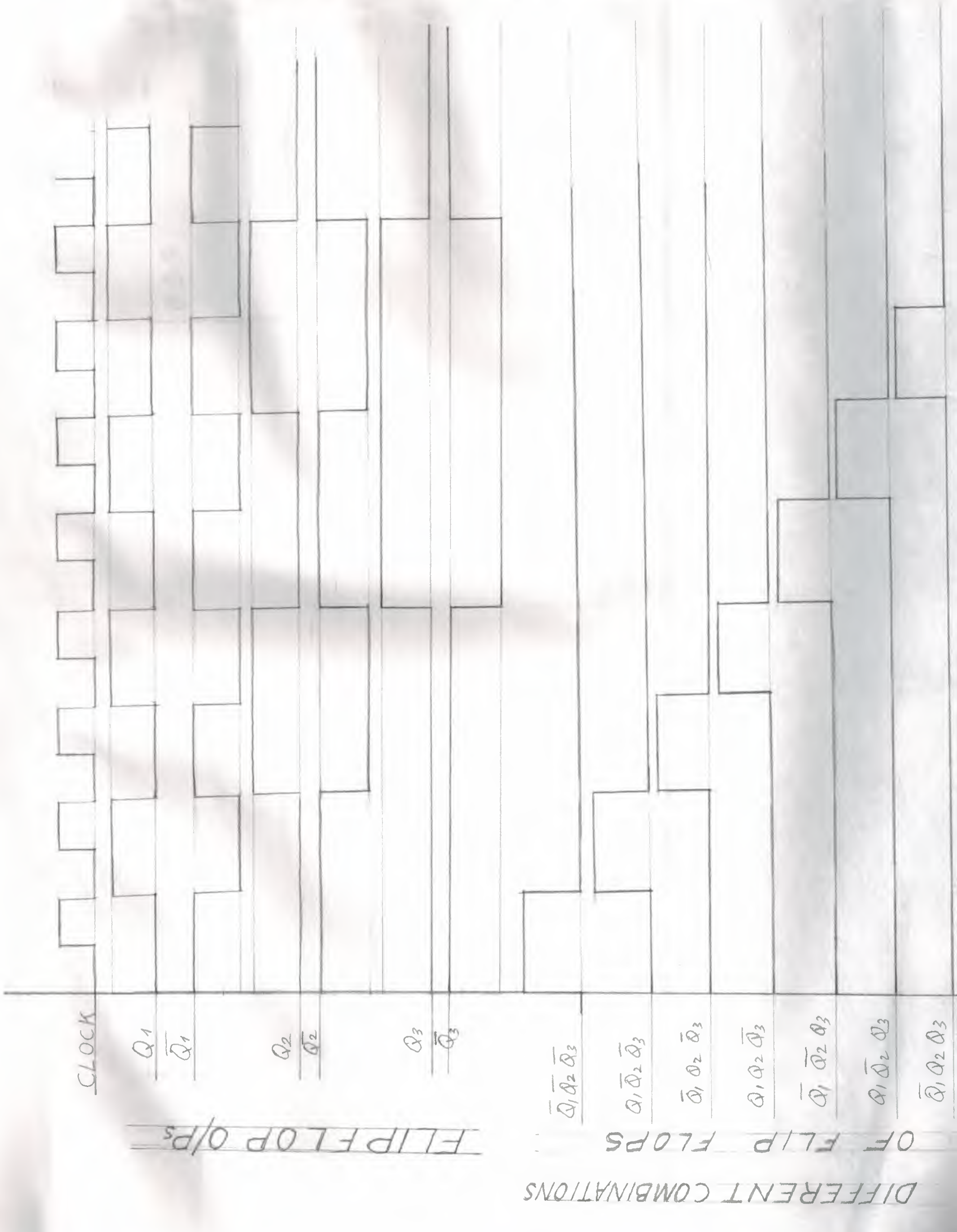
OF

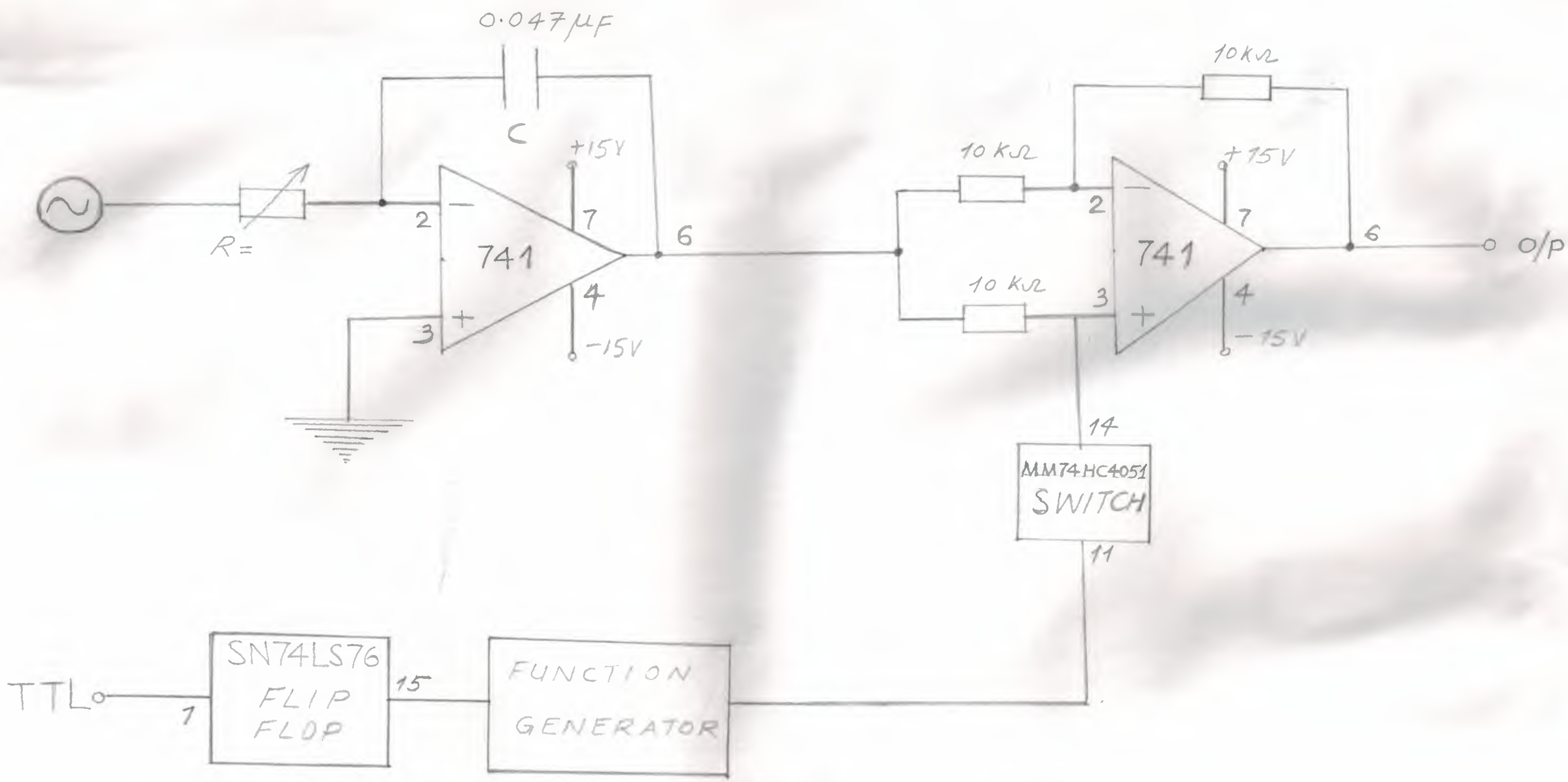
PROJECT

DIGITAL FUNCTION GENERATOR



OUTPUT OF FLIP FLOPS





CIRCUIT DIAGRAM FOR

PHASE SHIFT - KEYING

National Semiconductor

MM54HC30/MM74HC30 8-Input NAND Gate

General Description

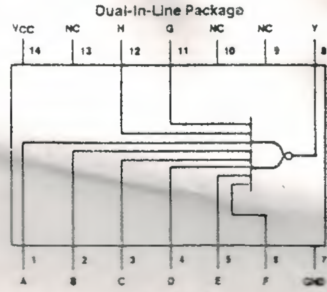
This NAND gate utilizes advanced silicon-gate CMOS technology to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits. This device has high noise immunity and the ability to drive 10 LS-TTL loads. The 54HC/74HC logic family is functionally as well as pin-out compatible with the standard 54LS/74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 20 ns
- Wide power supply range: 2–6V
- Low quiescent current: 20 µA maximum (74HC Series)
- Low input current: 1 µA maximum
- Fanout of 10 LS-TTL loads

Connection and Logic Diagrams

Dual-In-Line Package

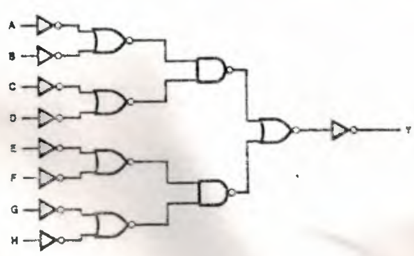


TL/F/5133-1

Top View

Order Number MM54HC30* or MM74HC30*

*Please look into Section 8, Appendix D for availability of various package types.



Y = ABCDEFGH

TL/F/5133-2

National Semiconductor

MM54HC00/MM74HC00
Quad 2-Input NAND Gate

General Description

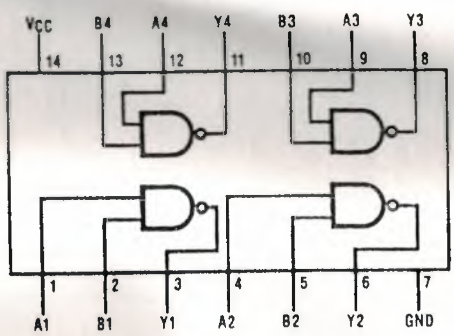
These NAND gates utilize advanced silicon-gate CMOS technology to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits. All gates have buffered outputs. All devices have high noise immunity and the ability to drive 10 LS-TTL loads. The 54HC/74HC logic family is functionally as well as pin-out compatible with the standard 54LS/74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 8 ns
- Wide power supply range: 2–6V
- Low quiescent current: 20 μA maximum (74HC Series)
- Low input current: 1 μA maximum
- Fanout of 10 LS-TTL loads

Connection and Logic Diagrams

Dual-In-Line Package



TL/F/5292-1

Top View

Order Number MM54HC00* or MM74HC00*

*Please look into Section 8, Appendix D for availability of various package types.

TL/F/5292-2

National Semiconductor

MM54HC11/MM74HC11 Triple 3-Input AND Gate

General Description

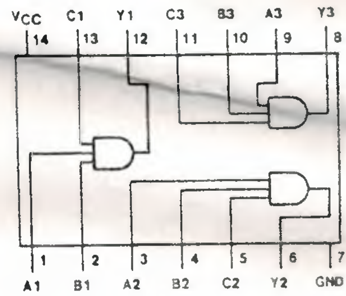
These AND gates utilize advanced silicon-gate CMOS technology to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits. All gates have buffered outputs, providing high noise immunity and the ability to drive 10 LS-TTL loads. The 54HC/74HC logic family is functionally as well as pin-out compatible with the standard 54LS/74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 12 ns
- Wide power supply range: 2–6V
- Low quiescent current: 20 μA maximum (74HC Series)
- Low input current: 1 μA maximum
- Fanout of 10 LS-TTL loads

Connection and Logic Diagrams

Dual-In-Line Package

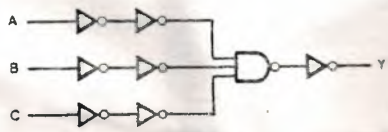


TL/F/5298–1

Top View

Order Number MM54HC11* or MM74HC11*

*Please look into Section 8, Appendix D for availability of various package types.



TL/F/5298–2

(1 OF 3 GATES)

National Semiconductor

MM54HC08/MM74HC08
Quad 2-Input AND Gate

General Description

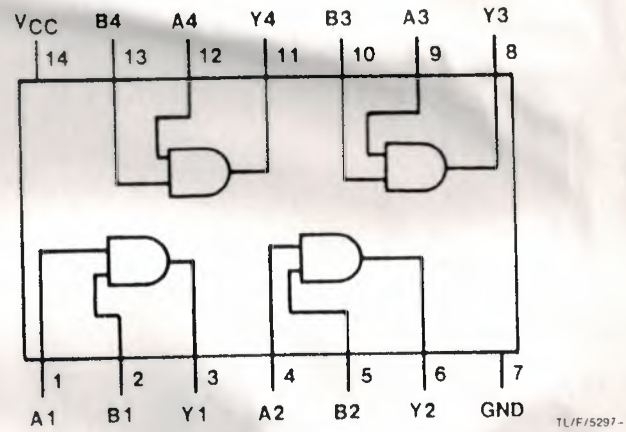
These AND gates utilize advanced silicon-gate CMOS technology to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits. The HC08 has buffered outputs, providing high noise immunity and the ability to drive 10 LS-TTL loads. The 54HC/74HC logic family is functionally as well as pin-out compatible with the standard 54LS/74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 7 ns (t_{PHL}), 12 ns (t_{PLH})
- Fanout of 10 LS-TTL loads
- Quiescent power consumption: 2 μA maximum at room temperature
- Low input current: 1 μA maximum

Connection Diagram

Dual-In-Line Package



Top View

Order Number MM54HC08 or MM74HC08

*Please look into Section 8, Appendix D for availability of various package types

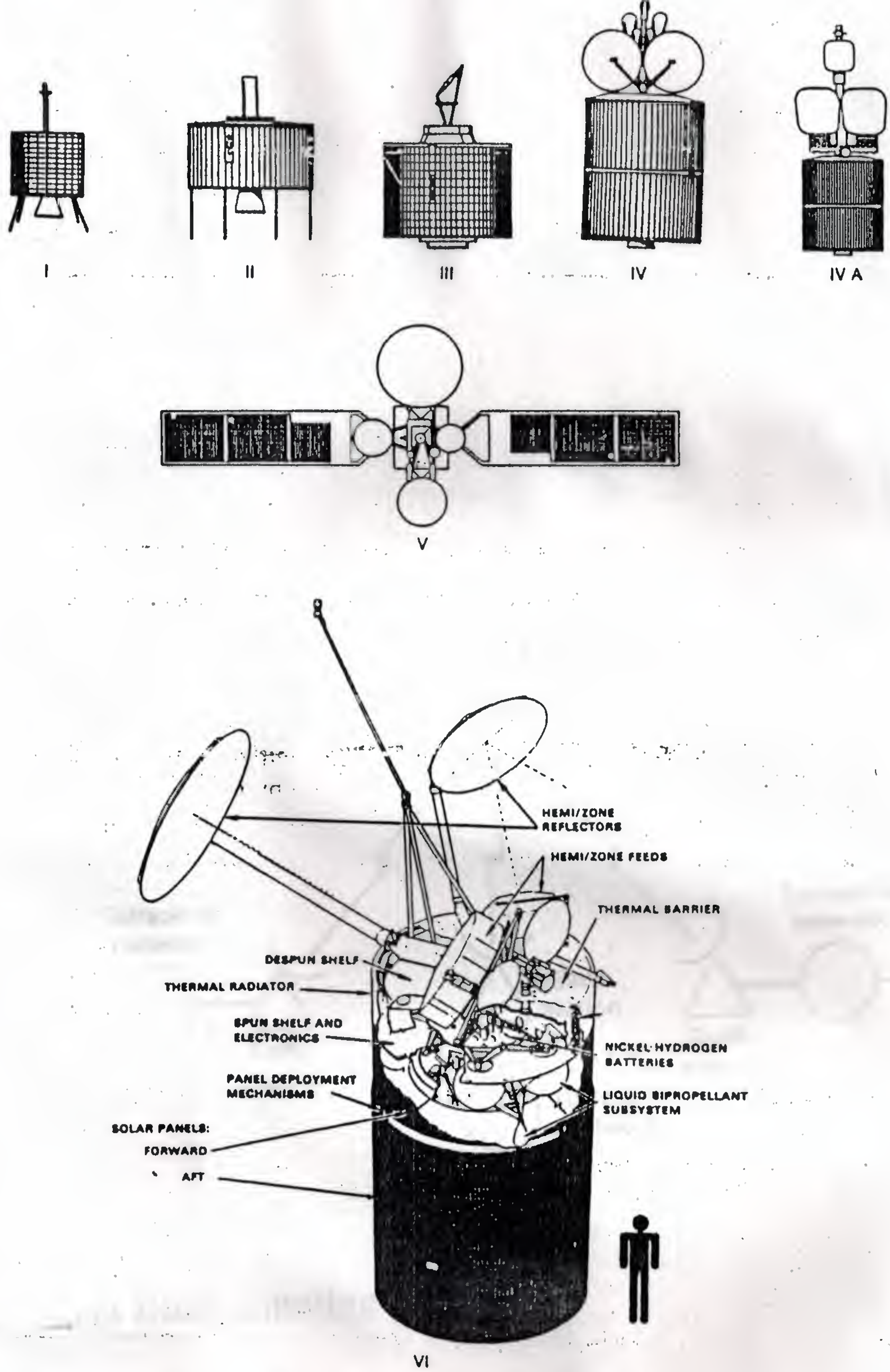


Fig.1.1 INTELSAT Satellite

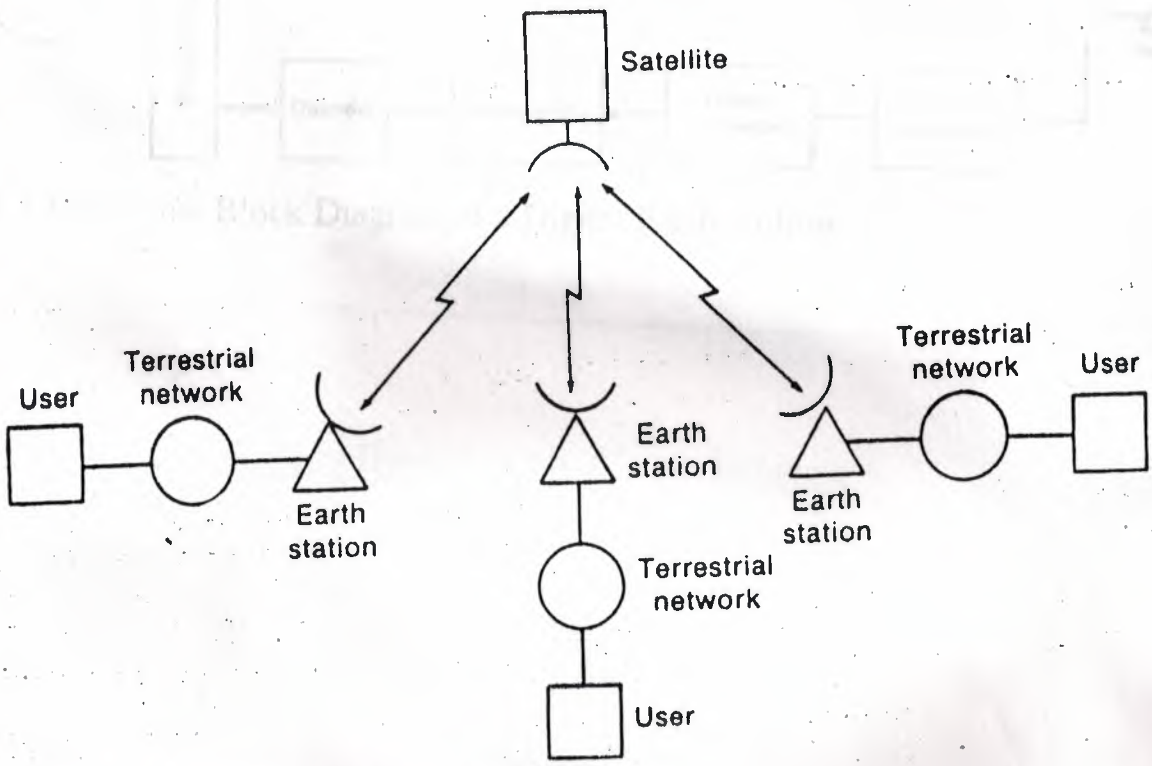


Fig.1.2 A Basic Satellite System

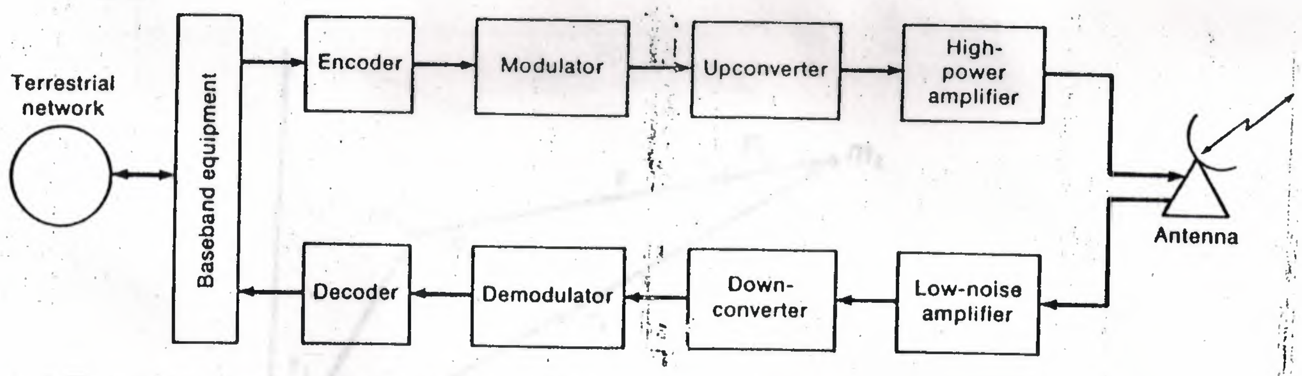


Fig.1.3 Functional Block Diagram of a Digital Earth Station

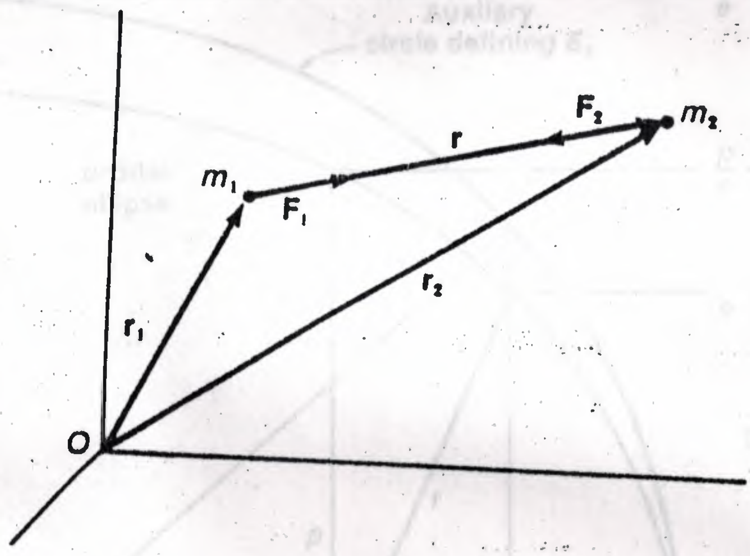


Fig.2.1 Satellite-Earth Coordinates

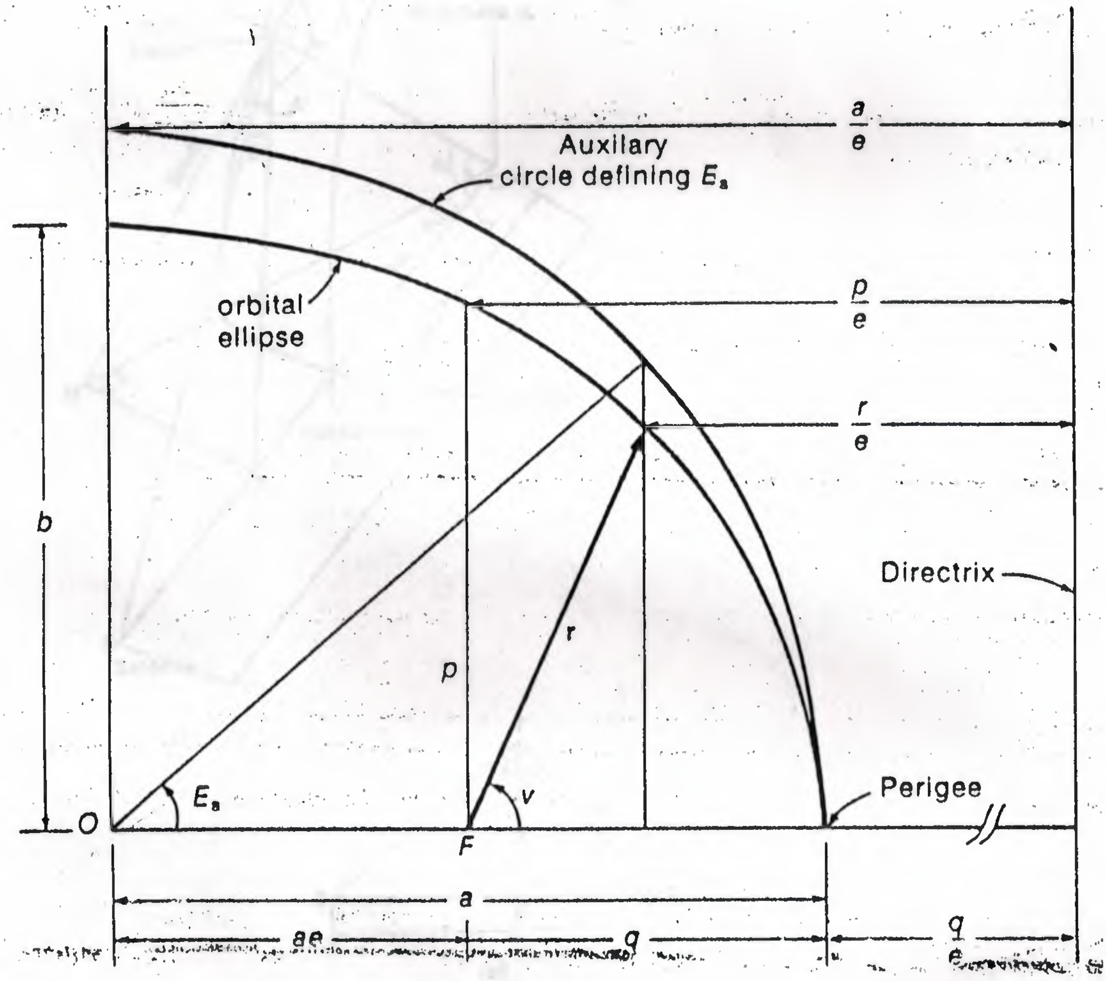


Fig.2.2 Satellite Orbit

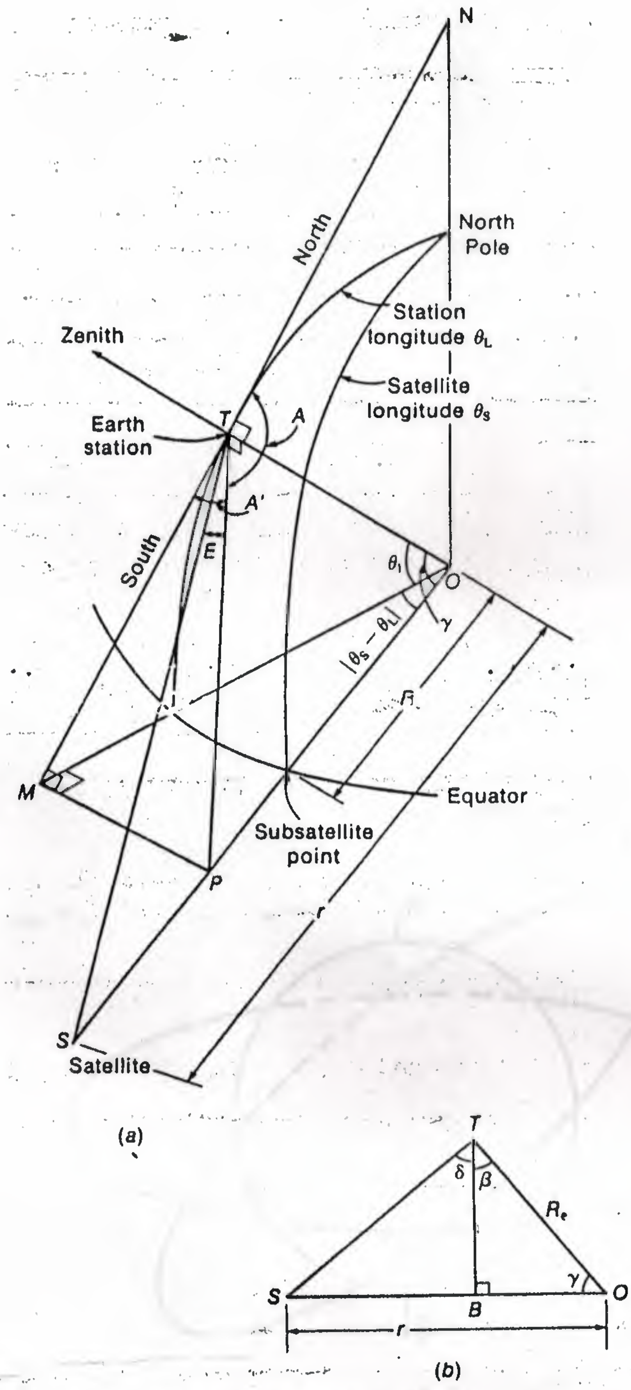


Fig.2.3 (a) Azimutte and Elevation (b) Triangle to Calculate Elevation

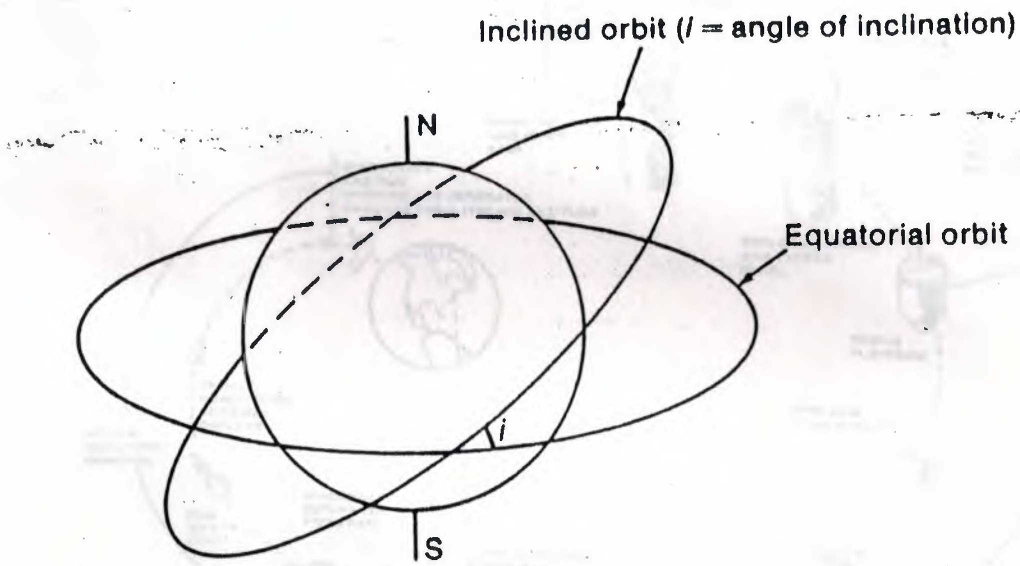


Fig.2.4 Inclined Orbit

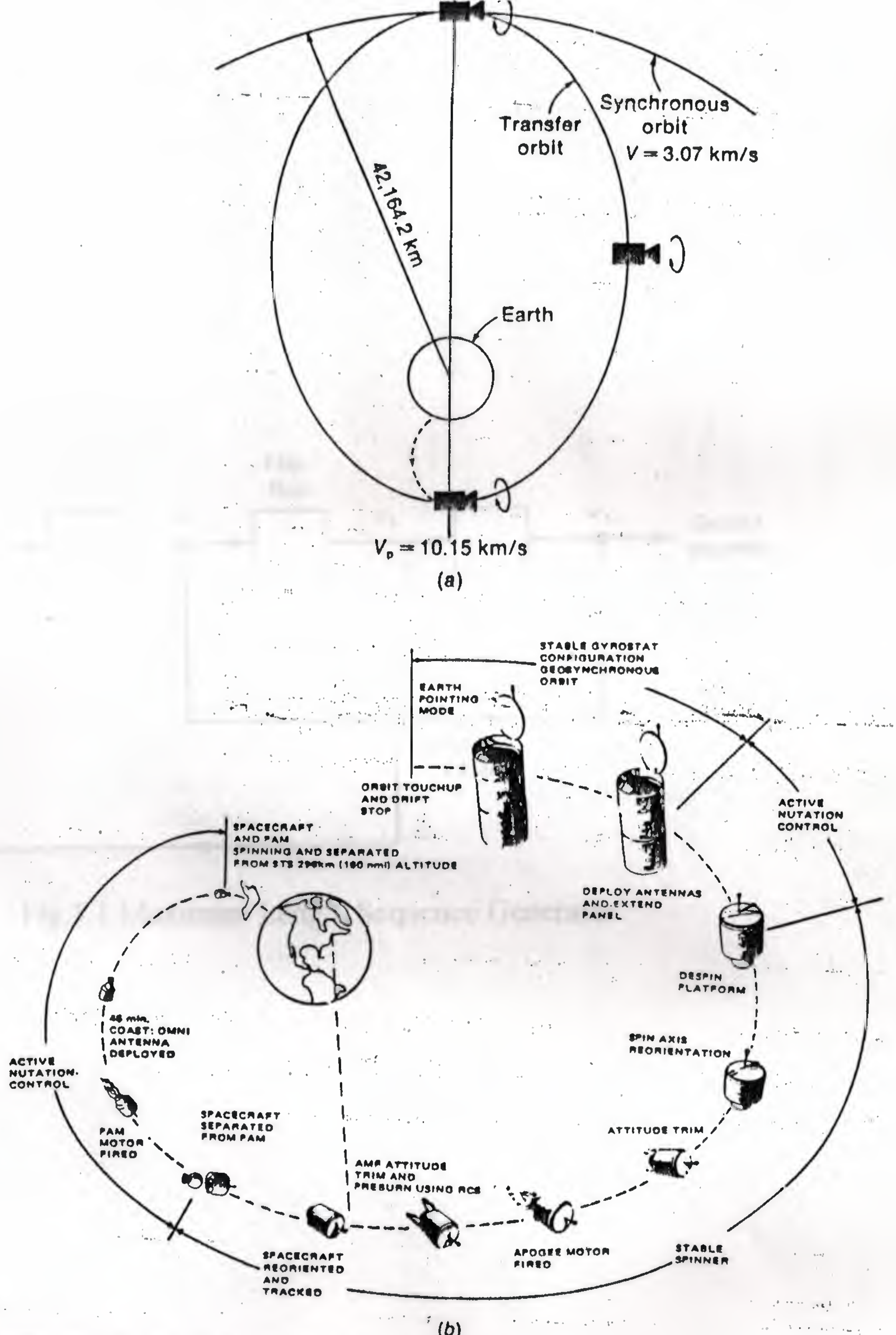


Fig.2.5 Placement of a Satellite in a Geostationary Orbit
(a) Concept (b) Actual Launch (Courtesy of Huges Air Craft Co.)

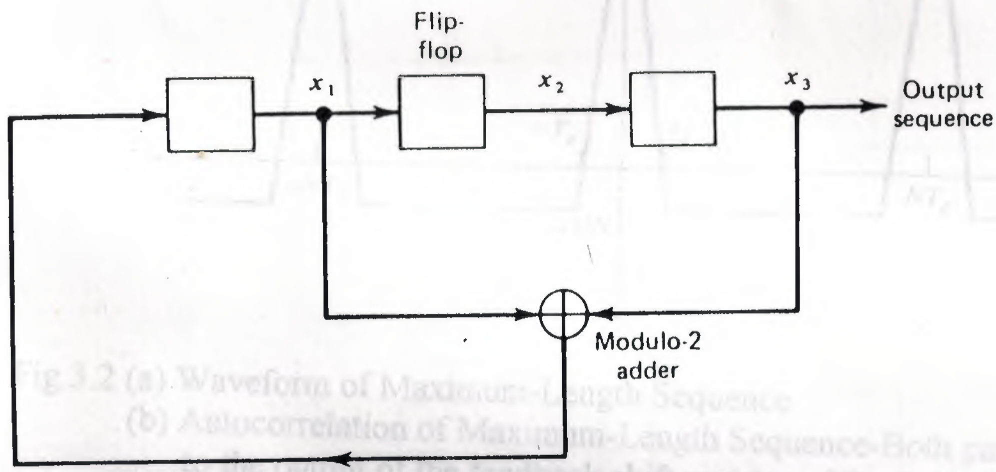


Fig.3.1 Maximum Length Sequence Generator

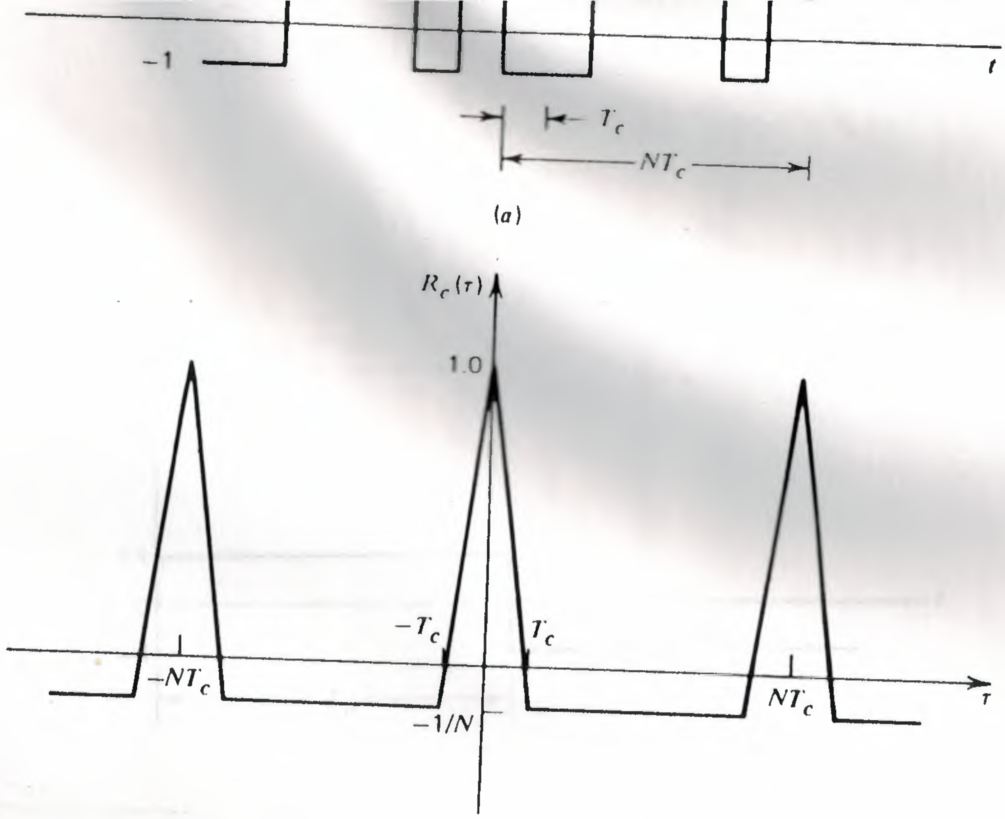


Fig.3.2 (a) Waveform of Maximum-Length Sequence
(b) Autocorrelation of Maximum-Length Sequence-Both parts refer to the output of the feedback shift recister of Fig.3.1

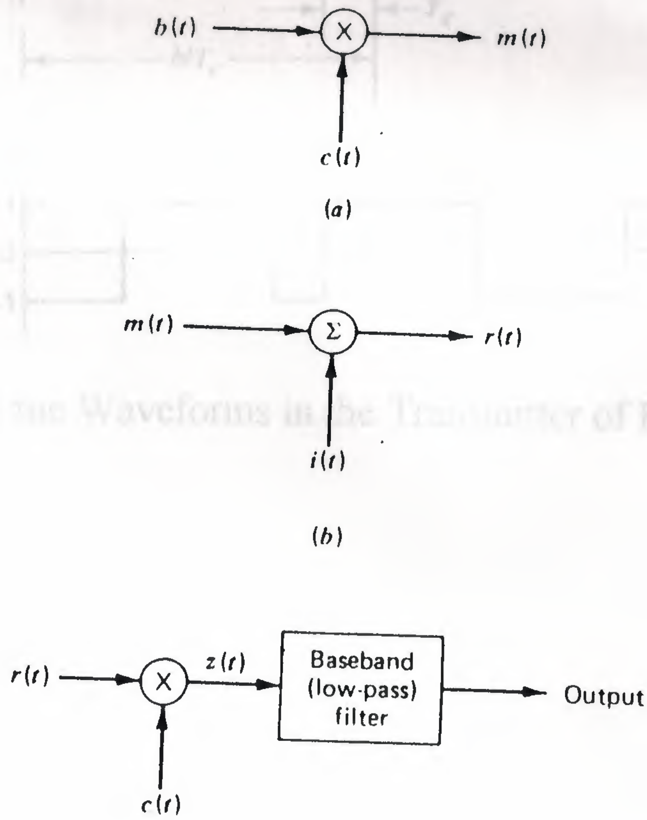


Fig.3.3 Idealized Model of Baseband Spread-Spectrum System.
(a) Transmitter (b) Channel (c) Receiver

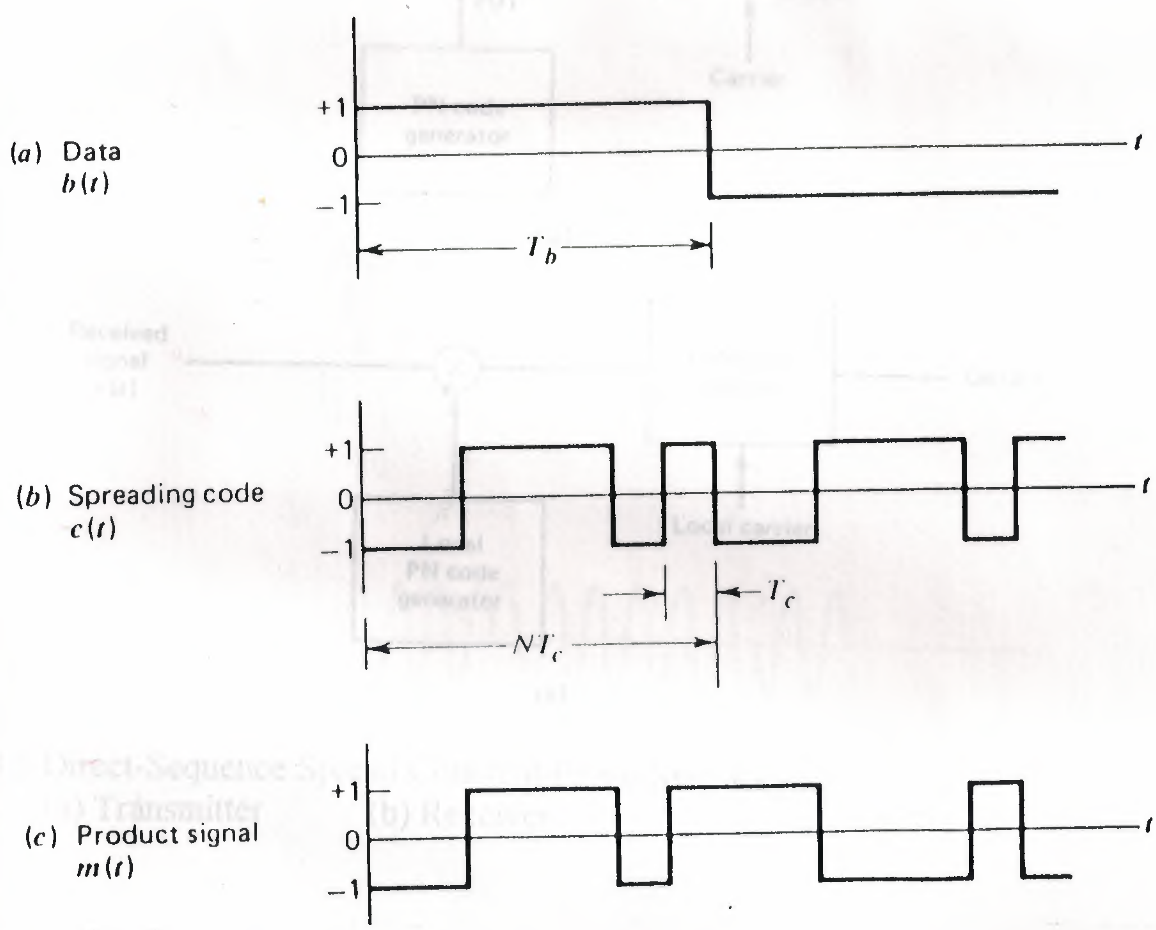


Fig.3.4 Illustrating the Waveforms in the Transmitter of Fig.3.3(a).

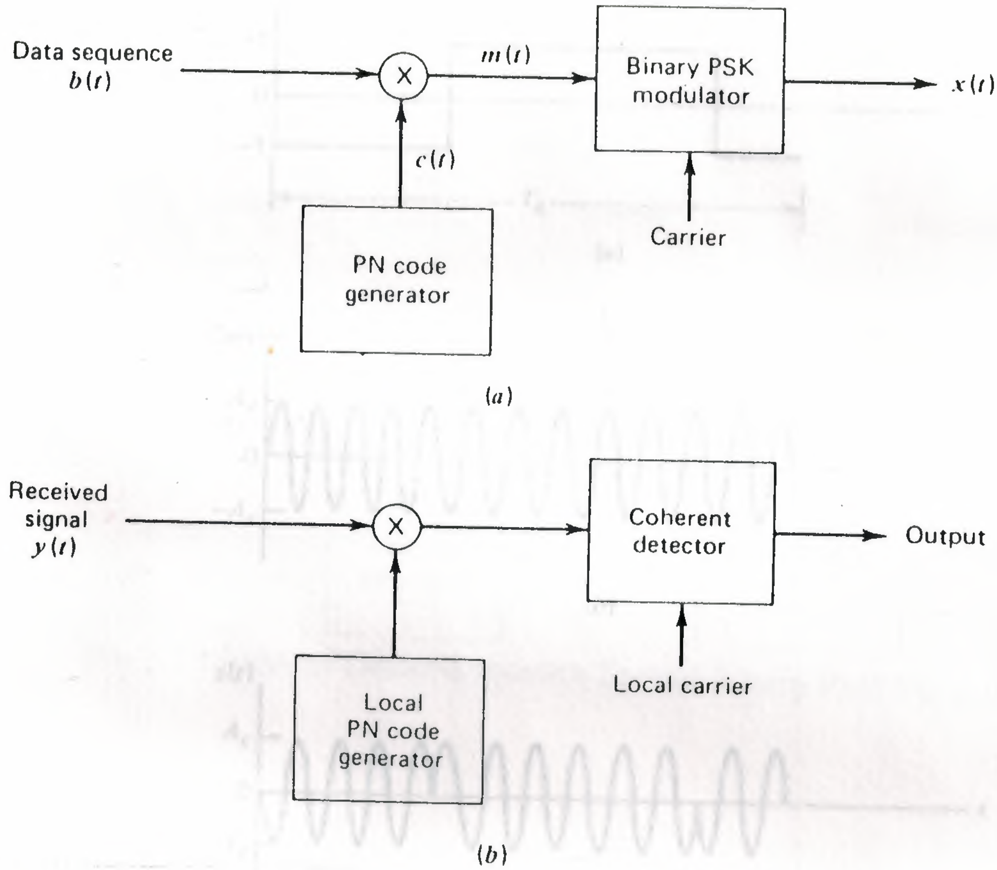


Fig.3.5 Direct-Sequence Spread Coherent Phase-Shift Keying
(a) Transmitter (b) Receiver

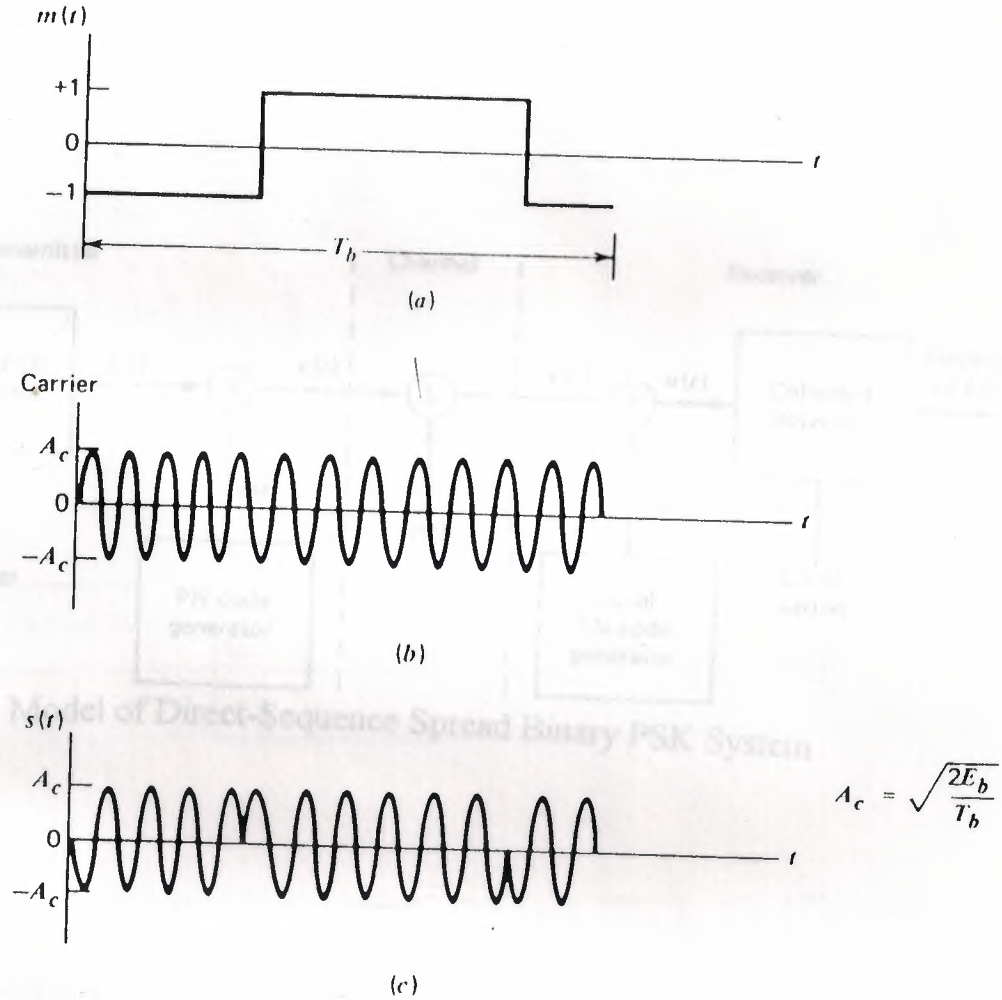


Fig.3.6 (a) Product Signal m(t) = c(t) b(t).
(b) Sinusoidal Carrier
(c) DS/BPSK

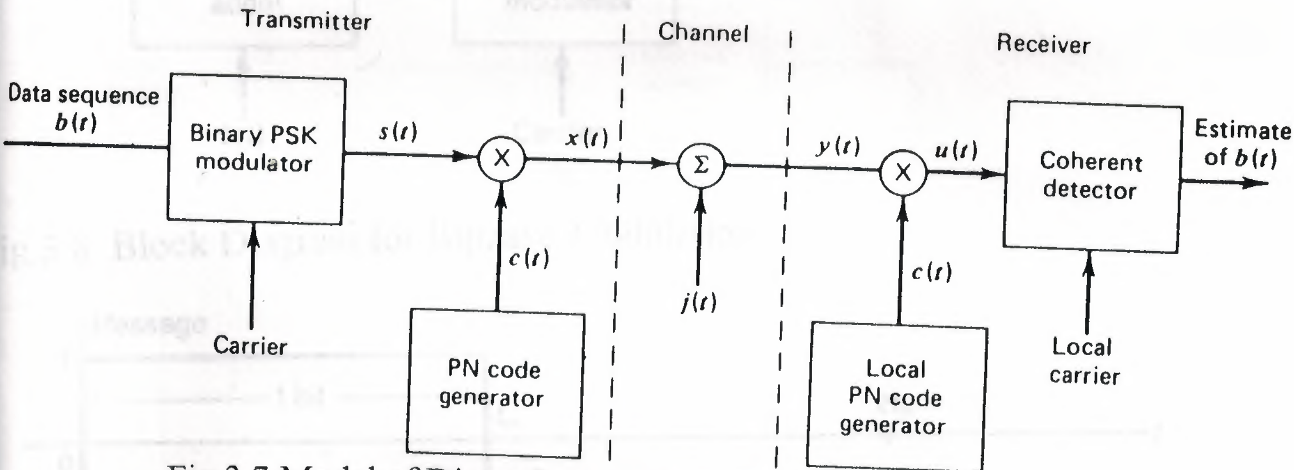


Fig.3.7 Model of Direct-Sequence Spread Binary PSK System

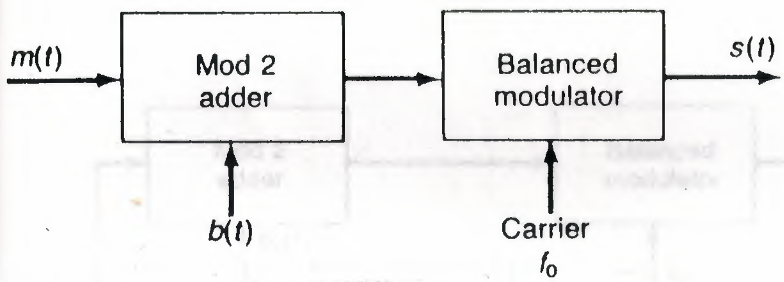


Fig.3.8 Block Diagram for Biphase Modulation

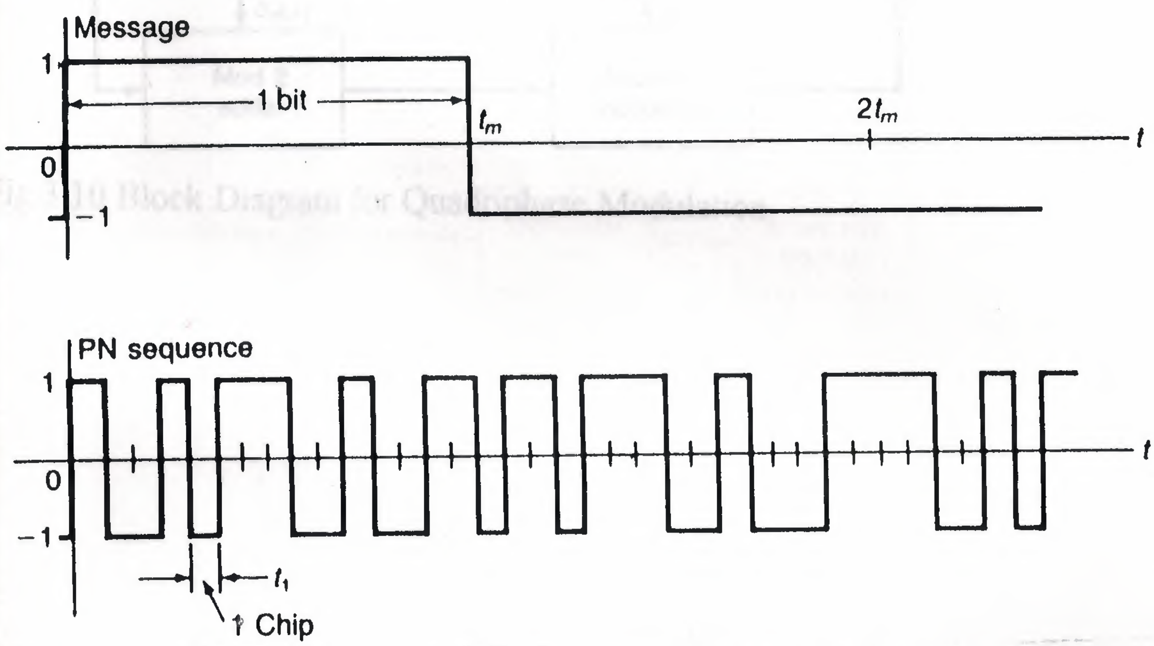


Fig.3.9 Relation Between the Code Sequence and the binary message

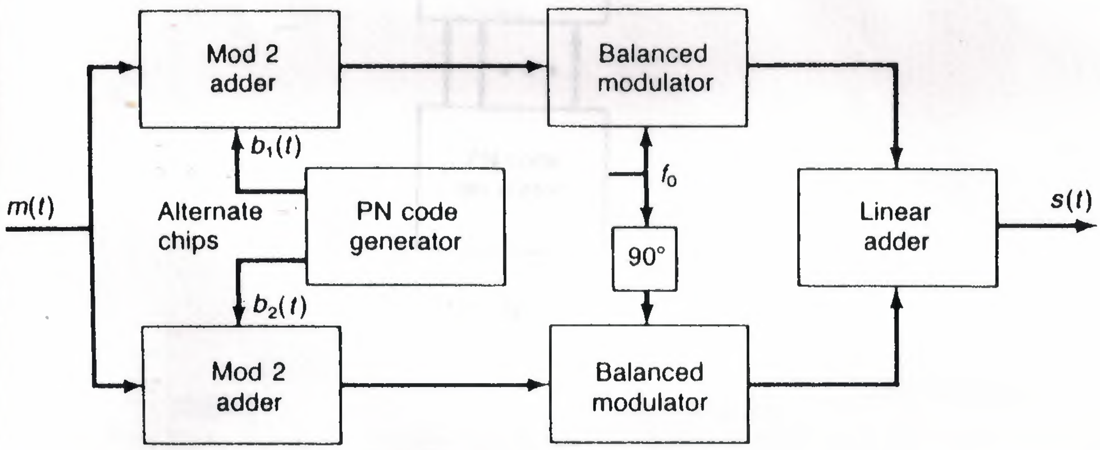
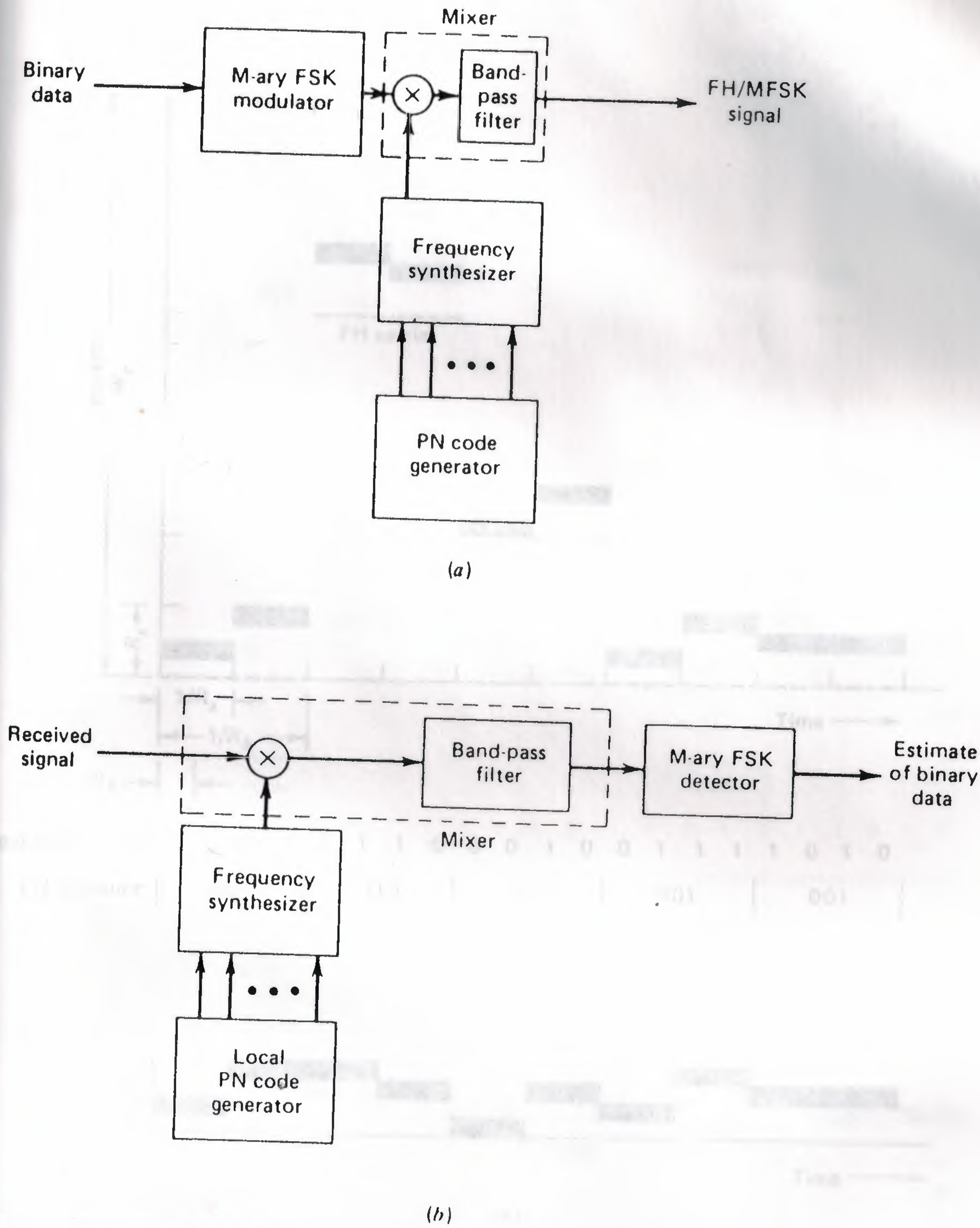
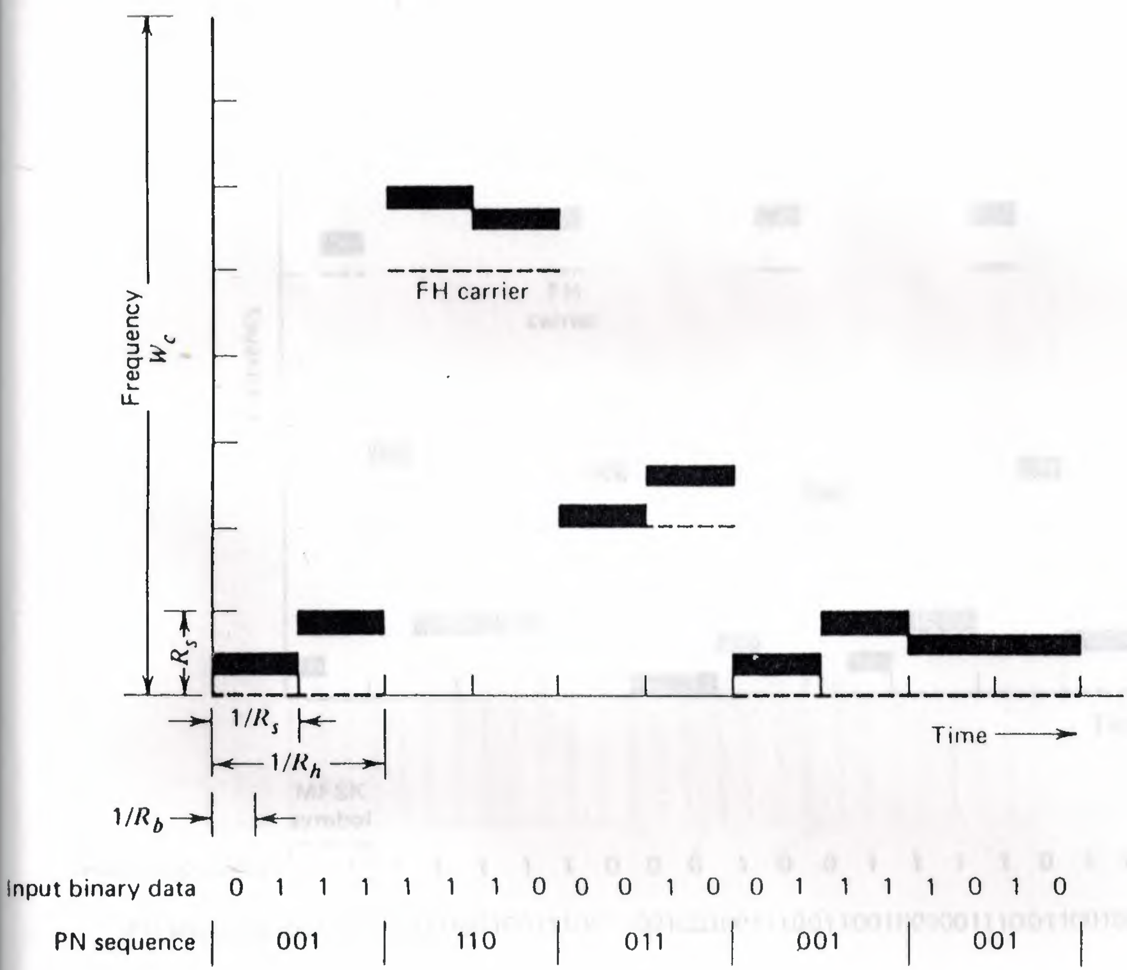


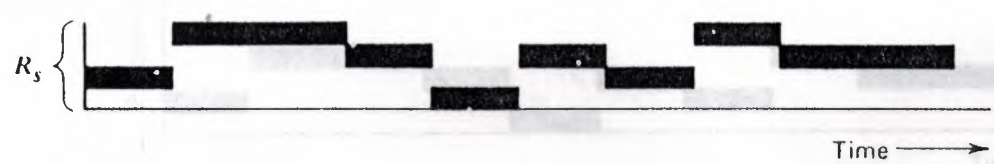
Fig.3.10 Block Diagram for Quadriphase Modulation



ig.4.1 Frequency Hop Spread M-ary Frequency-Shift Keying
(a) Transmitter (b) Receiver



(a)



(b)

Fig.4.2 Illustrating Slow-Frequency Hopping

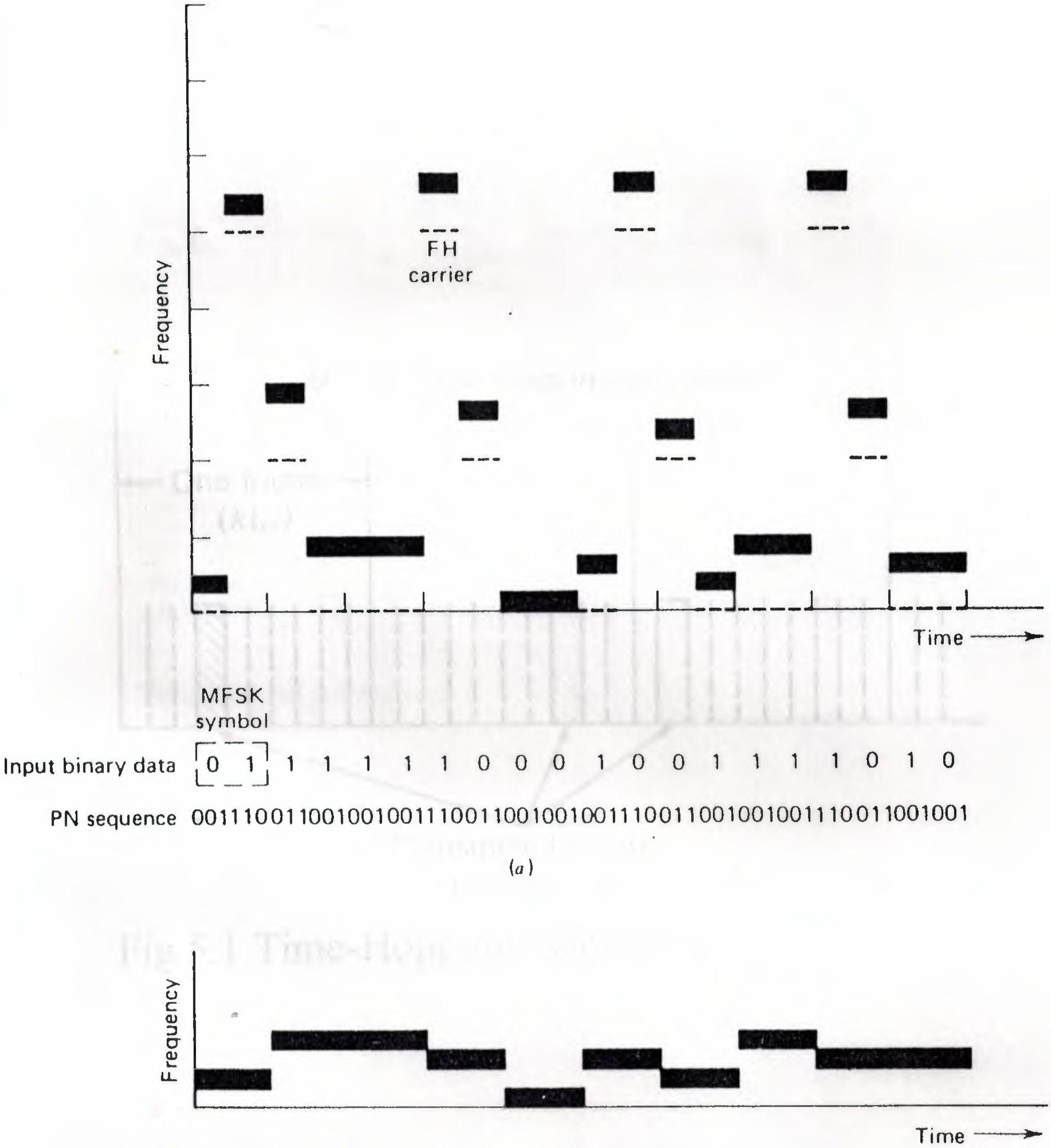


Figure 4.3 Illustrating fast-frequency hopping.

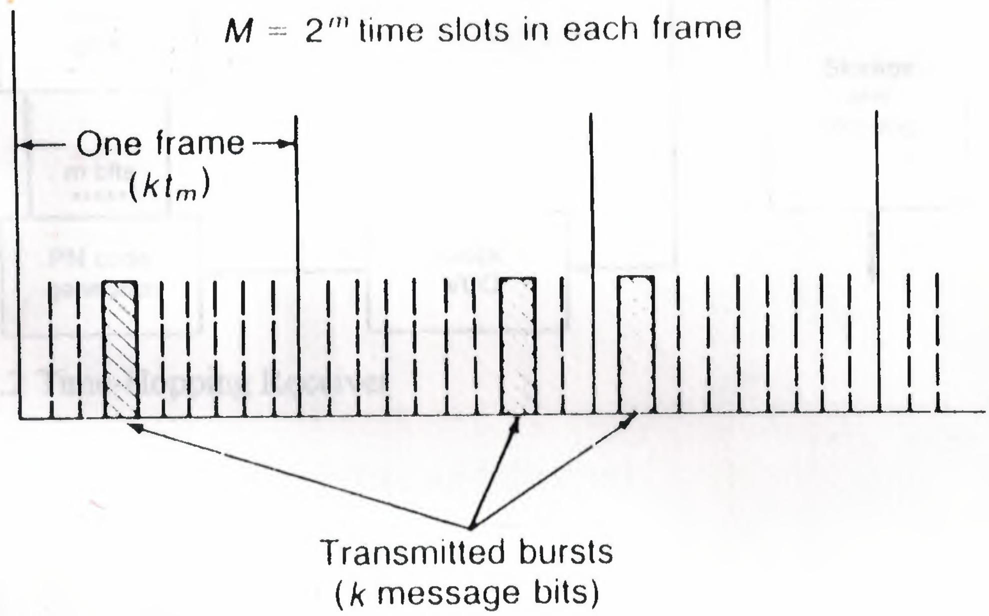


Fig.5.1 Time-Hopping Waveform

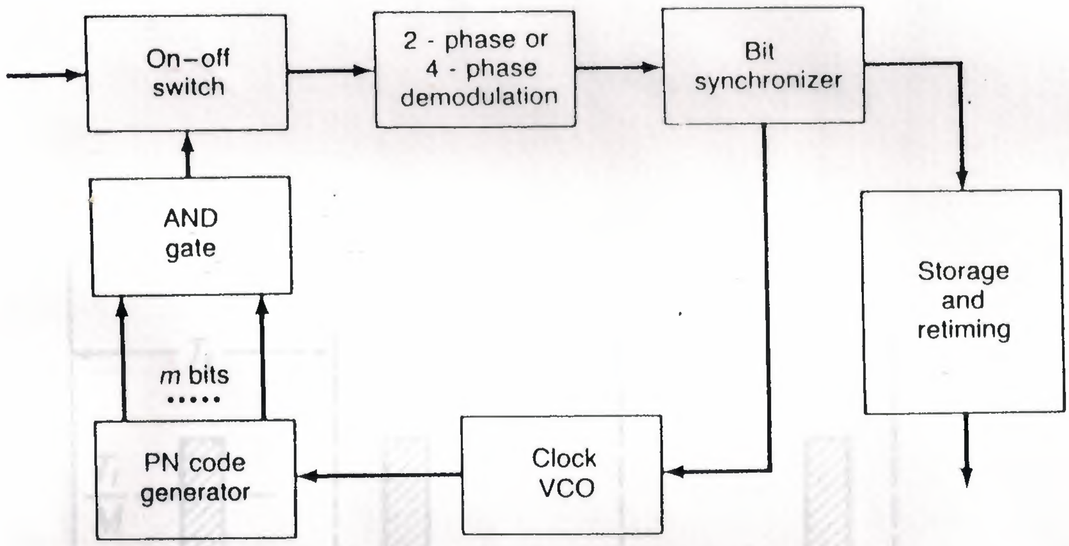


Fig.5.2 Time-Hopping Receiver

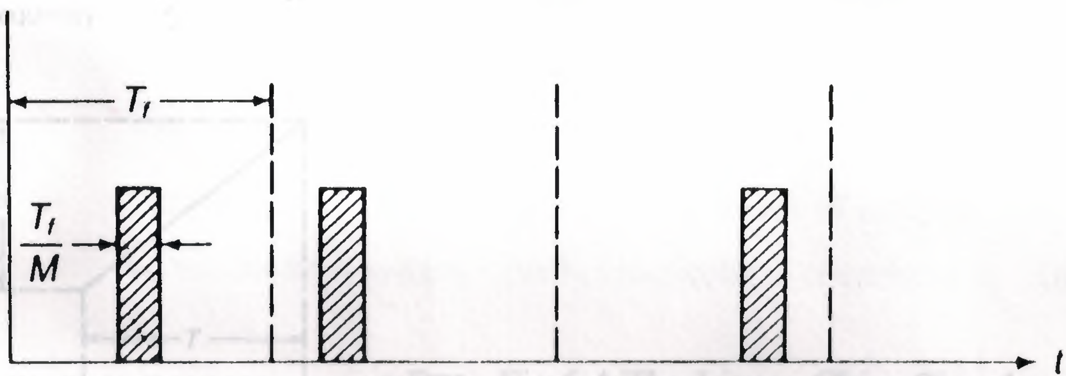


Fig.5.3 A Time-Hopping Signal

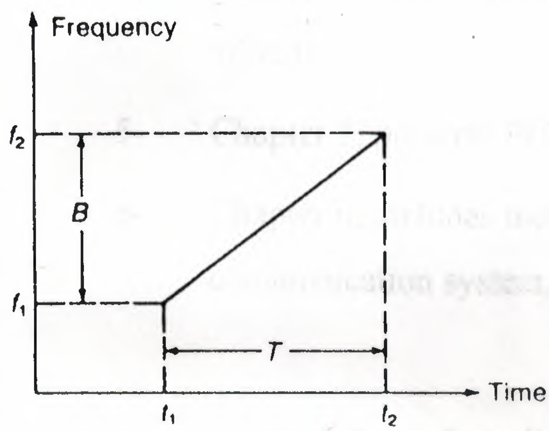


Fig.5.4 The Linear Chirp Signal

CONCLUSION

1- In chapter 1, is described elements of satellite communication system.

2- Chapter 2, is devoted to present satellite orbits and its description.

3- Chapter 3, presents the fundamental knowledge about spread-spectrum modulation.

4- Chapter 4, gives information about slow FH spread-spectrum system.

5- Chapter 5, presents PH spread-spectrum system.

6- Chapter 6, includes method of multiple access of satellite communication system, which in particular is considered as CDMA.

In the plan of realization was implemented digital generator (generates 128 binary signals) and phase shift keying modulator using modern integrated circuits.

I hope this project will be useful for students and engineers, specialized in spread-spectrum communication system.

The whole plan was realized on breadboard and can be used in the laboratory of telecommunication and data communication.

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ABBREVIATIONS

AWGIN: Additive White Gaussian Noise

BSS: Broadcasting Satellite Service

b/s: Bit per Second

CCIR: International Radio Counsultative Committee

CDMA: Code Division Multiple-Access

dB: Decibel

DS: Direct Sequence

DS/BPSK: Direct-Sequence spread Binary Phase-Shift Keying

EHF: Extreme High Frequency

ESA: European Space Agency

FDMA: Frequency Division Multiple-Access

FH: Frequency-Hopping

FH/MFSK: Frequency-Hop Spread M-ary Frequency-Shift Keying

FSK: Frequency-Shift Keying

GPS: Global Positioning System

HF: High Frequency

HZ: Hertz

IF: Intermediate Frequency

INTELSAT: International Telecommunications Satellite Organization.

ITU: International Telecommunication Union

LF: Low Frequency

LNA: Low-Noise Amplifier

LPF: Low Pass Filter

MF: Medium Frequency

NASA: National Aeronautics and Space Administration

PG: Processing Gain

PN: Pseudonoise

PSK: Phase-Shift Keying

RF: Radio Frequency

SHF: Super High Frequency

STS: Space Transport System

TDMA: Time Division Multiple-Access

TDRSS: Telecommunication Data Relay Satellite System

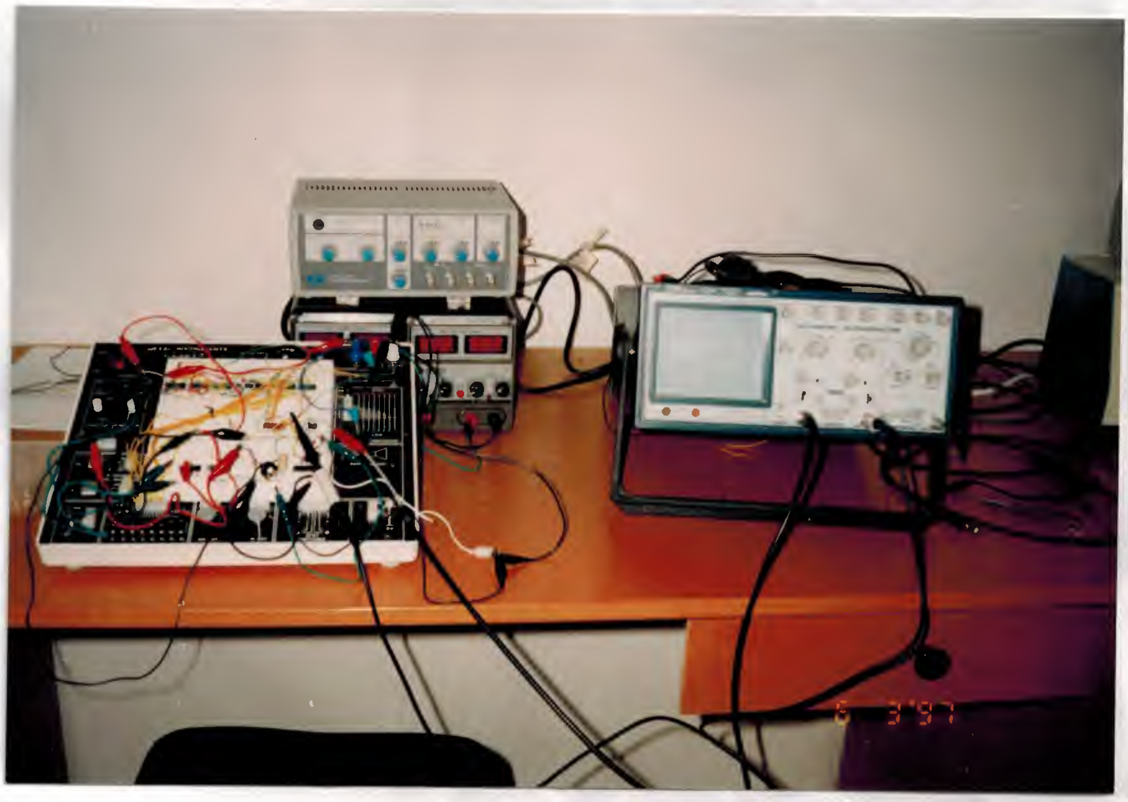
TH: Time-Hopping

UHF: Ultrahigh Frequency

VHF: Very High Frequency

VLF: Very Low Frequency

WARC: World Administrative Radio Frequency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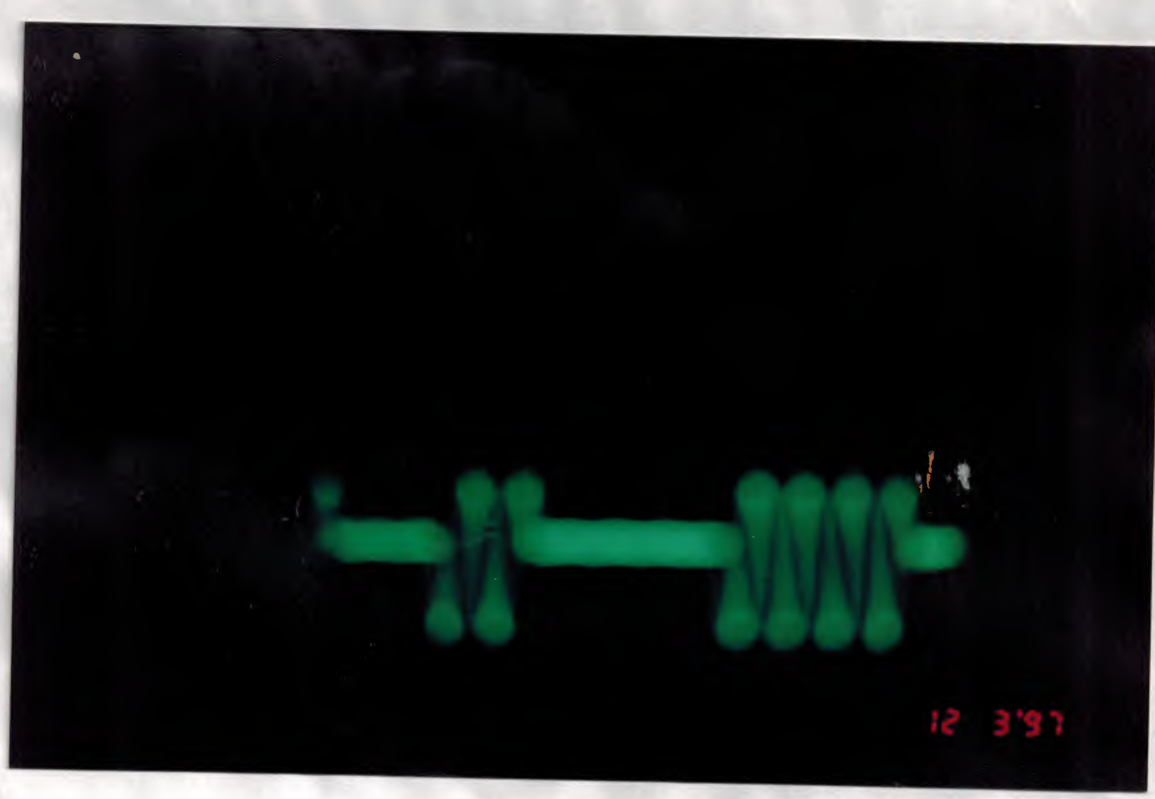
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