$$R_s = nR_h$$

$$\frac{1}{R_s} = \frac{1}{nR_h}$$

$$n \cdot T_s = T_c$$

01 11 10 00 . . .

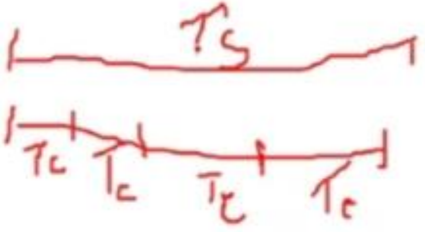
001 011

T_c

$$R_h = nR_s$$

$$\frac{1}{R_h} = \frac{1}{nR_s}$$

$$n \cdot T_c = T_s$$



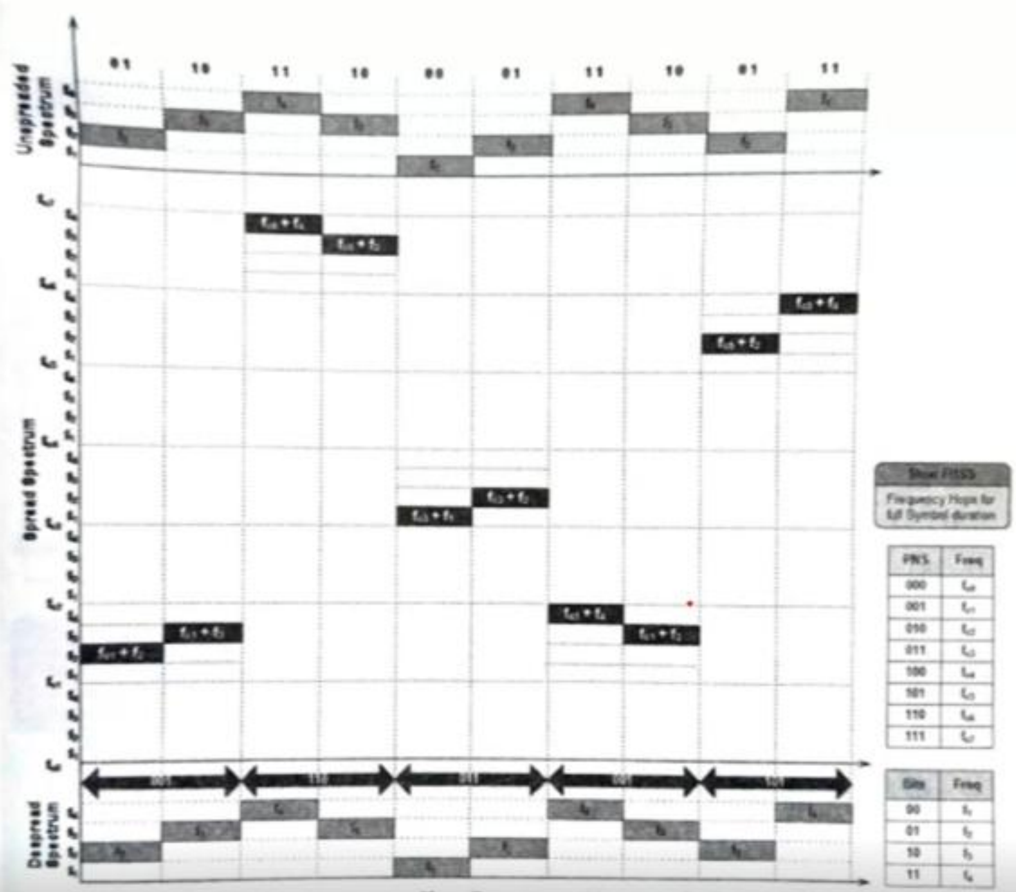
Slow Frequency Hopping

EXAMPLE 4

Figure 9.9*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 $2^4 - 1 = 15$. The FH/MFSK signal has the following parameters:

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

Navya Holla



Slow Frequency Hopping for k=3

Navya Holla

DP9.9. A PN sequence is generated using 4-stage linear feedback shift register as shown in Figure DP9.9(a), with initial condition $(C_3C_2C_1C_0) = (1000)$. This sequence is used in a slow FH/MFSK system. The FH/MFSK signal has the following parameters.

Number of bits per MFSK symbol $K = 2$

Number of MFSK tones $M = 2^K = 4$

Length of PN segment per hop $k = 3$

Total number of frequency hops $2^k = 8$

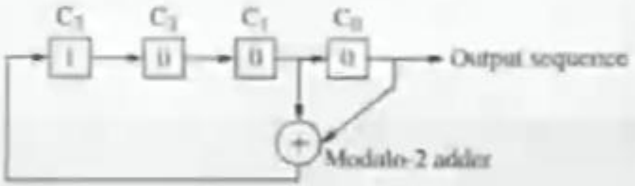


Figure DP9.9(a)

Determine the following:

a) Period of the PN sequence.
b) PN sequence for one periodic length.
c) Illustrate the variation of the frequency of FH/MFSK signal for one complete period of the PN sequence. Assume that the carrier hops to a new frequency after transmitting two MFSK symbols or four information bits. Assume binary data sequence to be 100011010000111111001.
d) Sketch the variation of dehopped frequency with time.

Applications

- Multipath Suppression
- Code Division Multiple Access

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 code is 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 a gradual degradation in performance as the number of users is 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).

Solution:

a) The period of the PN sequence is $2^4 - 1 = 15$.

b) For the initial condition shown, the PN sequence is obtained by writing all the successive states of the shift register (SR), for one period. Table DP9.2 gives the successive states, the fed back bit and the output bit.

ii) The PN sequence of one periodic length is 000100110101111. The carrier is hopped to a new frequency after transmitting two MFSK symbols or four information bits. Number of bits per MFSK symbol $K = 2$. There are hence four MFSK frequencies corresponding to dibits 00, 01, 10 and 11. Length of PN segment per hop $k = 3$.

Table DP9.2

States of SR				Fed back bit	Output bit
C_3	C_2	C_1	C_0	$C_3 = C_1 \oplus C_0$	C_0
1	0	0	0	0	0
0	1	0	0	0	0
0	0	1	0	1	0
1	0	0	1	1	1
1	1	0	0	0	0
0	1	1	0	1	0
1	0	1	1	0	1
0	1	0	1	1	1
1	0	1	0	1	0
1	1	0	1	1	1
1	1	1	0	1	0
1	1	1	1	0	1
0	1	1	1	0	1
0	0	1	1	0	1
0	0	0	1	1	1
1	0	0	0	Repeats	Repeats

Hence, there are $2^3 = 8$ hopping frequencies corresponding to each block of 3 PN sequence bits.

Let the hopping carrier frequencies corresponding to each block of 3 bits be selected as shown in Table DP9.3.

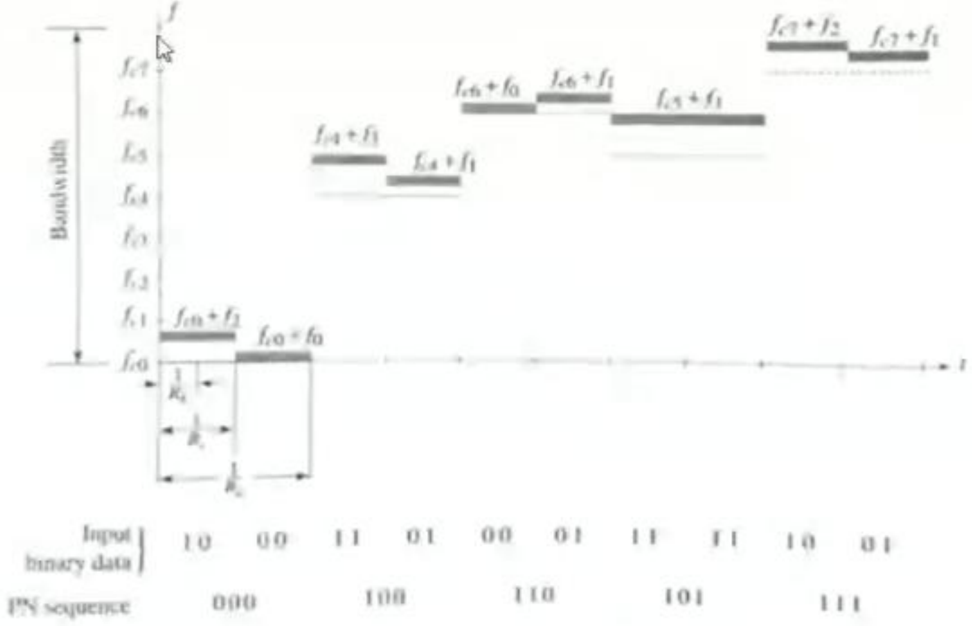
Table DP9.3

PN sequence segment	Hopping carrier frequency in Hz
000	f_{c0}
001	f_{c1}
010	f_{c2}
011	f_{c3}
100	f_{c4}
101	f_{c5}
110	f_{c6}
111	f_{c7}

The 4, MFSK tones be as shown in Table DP9.4.

Table DP9.4

Bits of MFSK symbol	MFSK tone in Hz
00	f_0
01	f_1
10	f_2
11	f_3



Transmitted frequencies versus time for the given binary data and PN sequence.

DP9.10. In a fast FH/MFSK system, the signal has the following parameters:

Number of bits per MFSK symbol: $K = 2$
Number of MFSK tones: $M = 2^K = 4$
Length of PN segment per hop: $k = 3$
Total number of frequency hops, $2^3 = 8$
Number of hops per MFSK symbol $= 2$
Period of PN sequence: $L = 15$.

i) Determine the relation between bit rate and chip rate.
ii) Sketch the variation of frequency of the transmitted signal with time. Assume binary data sequence to be 01101100 and one period of PN sequence is 111100010011010.
iii) Sketch the dehopped MFSK signal.

Solution:

i) In a fast FH/MFSK, there are multiple hops per MFSK symbol. Hence in a fast FH/MFSK system, each hop is a chip. In this example there are 2 bits/MFSK symbol and 2 hops/MFSK symbol. Hence bit rate R_b = hop rate R_h = chip rate R_c.

ii) Let the MFSK tones be denoted by f_0, f_1, f_2 and f_3 corresponding to MFSK symbols 00, 01, 10, 11, respectively.

Let the hopping carrier frequencies be denoted by: $f_{c0}, f_{c1}, f_{c2}, f_{c3}, f_{c4}, f_{c5}, f_{c6}$ and f_{c7} which correspond to the PN sequence segments 000, 001, 010, 011, 100, 101, 110, and 111, respectively.

During a hopping interval, if carrier frequency is f_{cj} and MFSK tone is f_i, then the transmitted frequency is $f_{cj} + f_i$.

The transmitted frequency and dehopped MFSK signal are shown in Figure DP9.10(a) and (b) respectively.

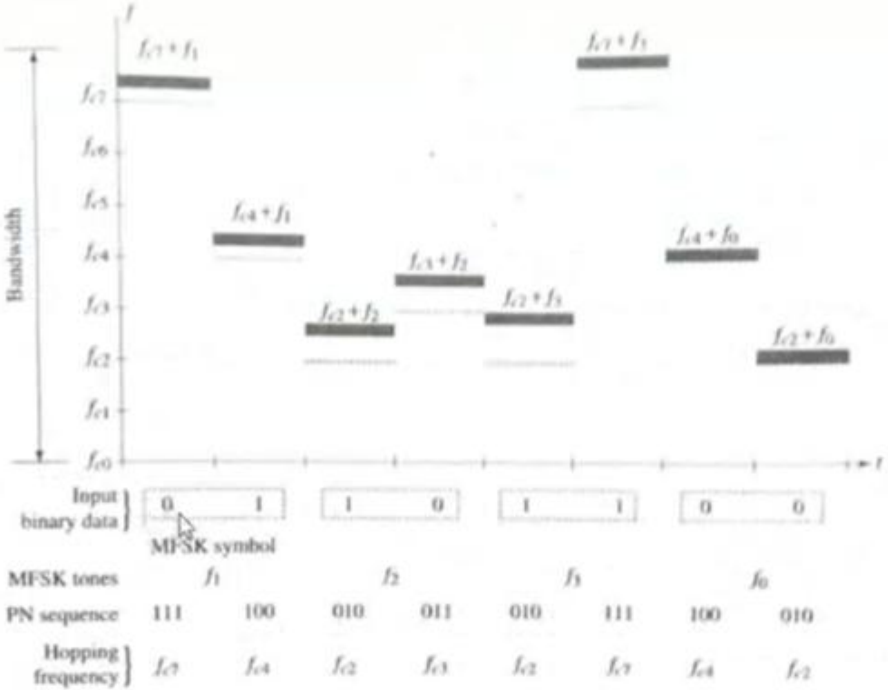


Figure DP9.10(a)

Figure DP9.10(b)