2.6.8 Transmitter for Digital Data (IMP

- *Figure 2.24* shows the simplified block diagram of a radio transmitter for digital data.
- The first step is digital modulation of data stream into analog baseband signal. Any of the digital modulation schemes discussed in the previous sections can be used.
- The baseband signal is then subject to analog modulation to shift its center frequency.
- The signal is then transmitted via the antenna.

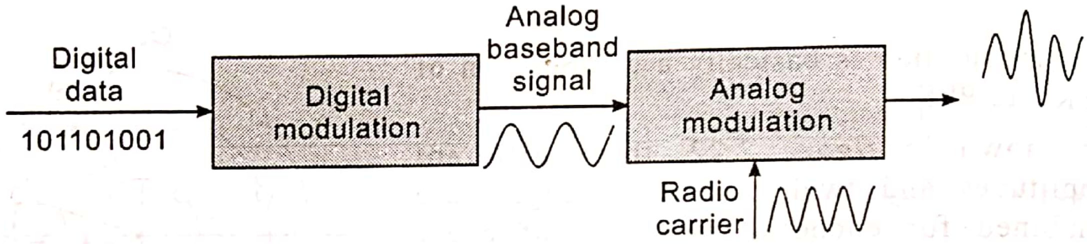

Fig. 2.24 : Transmission of Digital Data

2.6.9 Receiver for Digital Data (IMP

- As shown in *figure 2.25*, the receiver receives analog signal via its antenna and then demodulates the signal to generate the analog baseband signal.
- Synchronization is required between the sender and the receiver to detect the bits and frames.
- After synchronization, the receiver can detect whether the signal represents binary 1 or 0.

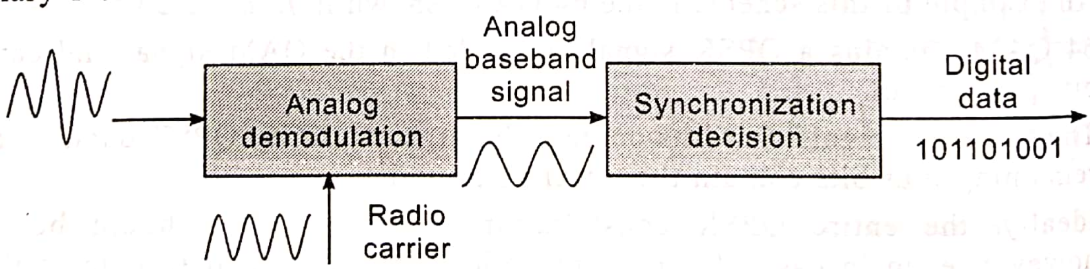

Fig. 2.25 : Receiver for Digital Data

2.7 Spread Spectrum (V.IMP

Q.1. What are the main benefits of spread spectrum ? How can spreading be achieved ? How can a DSSS system benefit from multipath propagation ?
[Dec. 06, Dec. 10, May 12, Dec. 12] (10/15 M

Note: *Spreading can be achieved by using DSSS or FHSS, explain both in short, also add about Rake receiver.*

Q.2. Explain what is spread spectrum. How can spreading be achieved ? What are the merits of spread spectrum technique ? **[May 09] (10 M**

Q.3. What are benefits of spread spectrum system ? **[Dec. 12] (5 M**

Q.4. Explain different types of spread spectrum technique used in cellular system. **[May 13] (5 M**

- It involves spreading the bandwidth that is needed to transmit the data.
- *Figure 2.26* shows the basic steps involved in this technology.
  (a) It is the idealized narrowband signal that is to be transmitted by the sender.
  (b) This narrowband signal is first converted into broadband signal i.e. the signal is spread. The energy needed to transmit the signal is still the same; however, the required power level reduces.
  (c) During transmission, narrowband as well as broadband interference gets added to the spread signal.
  (d) The receiver now has to despread the received signal. The original broadband signal (containing user data) is converted back to a narrowband signal. The narrowband interference that was added is spread, whereas the broadband interference is left as it is.
  (e) The signal is now applied to a bandpass filter that cuts off the frequencies to the left and right of the narrowband signal. The original user signal can now be recovered.

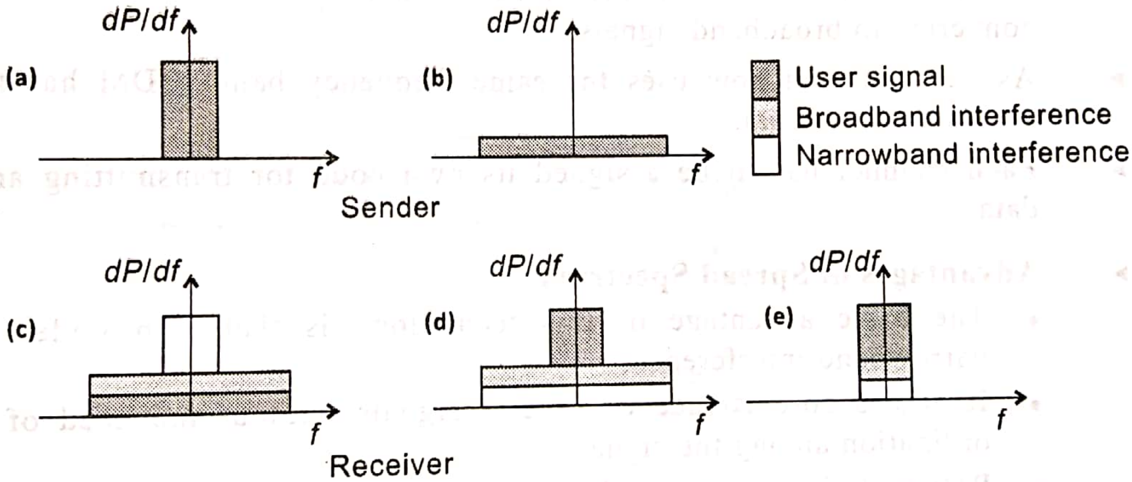

Fig. 2.26 : Spreading and Despreading of the User Signal

- The above scenario can also be applied simultaneously to many channels.

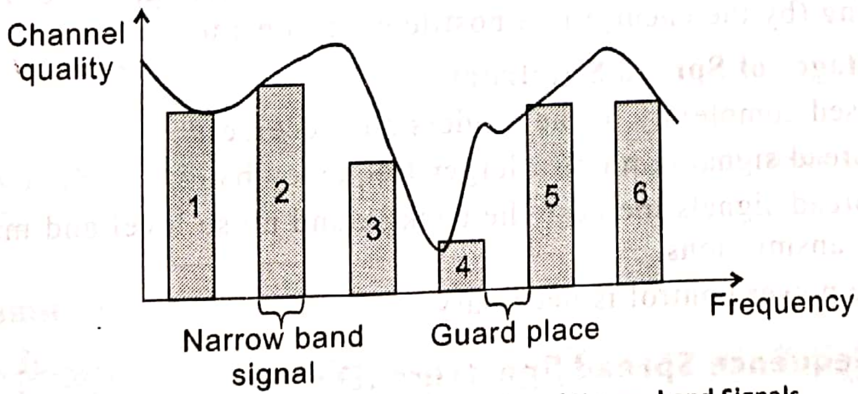

Fig. 2.27 : Multiple Channels Making Use of Narrowband Signals

- *Figure 2.27* shows a snapshot of the channel quality of six channels using FDM. The situation may be completely different at the next instant.
- Each channel has its own narrowband frequency of transmission. Guard spaces are required between the channels to avoid adjacent channel interference.

- Using FDM requires careful planning of the frequencies. Also, we can see tha the quality of channels 3 and 4 is too bad (due to narrowband interference) t recover the data.
- In order to solve these problems, we can apply spread spectrum to all the si channels.

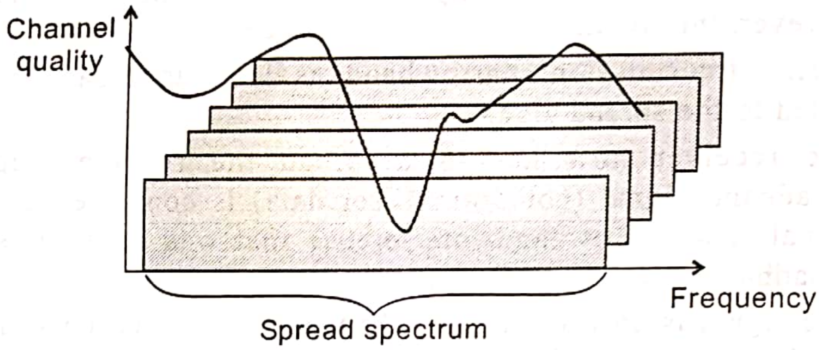

Fig. 2.28 : Spread Spectrum to Avoid Narrowband Interference

- As shown in *figure 2.28*, the narrowband signals for each of the channels are converted to broadband signals.
- As each channel now uses the same frequency band, CDM has to be used to separate each signal.
- Each channel has to be assigned its own code for transmitting and recovering data.
- **Advantages of Spread Spectrum**
  - The basic advantage of this technology is that it provides resistance to narrowband interference.
  - It allows co-existence of several signals without the need of dynamic co-ordination among the signals.
  - Relatively high security allows use in military applications. In fact, one of the key applications of spread spectrum is for building anti-jam communication systems, which is a communication system designed to resist intentional jamming (by the enemy) in a hostile environment.
- **Disadvantages of Spread Spectrum**
  - Increased complexity of the senders and receivers.
  - The spread signal requires a larger frequency band.
  - The spread signals increase the background noise level and may interfere with other transmissions.
  - Precise power control is necessary.

2.7.1 Direct Sequence Spread Spectrum (DSSS) (V.IMP)

Q.1. ***What is the use of spread spectrum ? Sketch the block diagram of the transmitter and receiver of DSSS. Explain what each block does and what the signal looks like (in time and/or frequency domains) at each location in the block diagram with an example.*** **[May 11] (10 M)**

- In this scheme, the user signal is spread by performing an XOR with a fixed sequence called *chipping sequence*.
- As shown in *figure 2.29*, a user signal 01, is XORed with the chipping sequence 0110101, the resulting signal is either 0110101 (if the user bit is 0) or its complement 1001010 (if the user bit is 1).
- Each user bit has duration t_b. The chipping sequence consists of smaller pulses called chips each having duration t_c.
- The spreading factor $S = t_b/t_c$, determines the bandwidth of the spread signal. Thus, if the original signal needed a bandwidth B, the spread signal would require a bandwidth $S \times B$.
- While this example uses a spreading factor of 7 (only), real life applications use spreading factors between 10 and 100; military applications may even use spreading factors of upto 10,000.
- Barker codes are usually used for spreading the signals as these codes are insensitive to multipath propagation and also exhibit good robustness against interference.

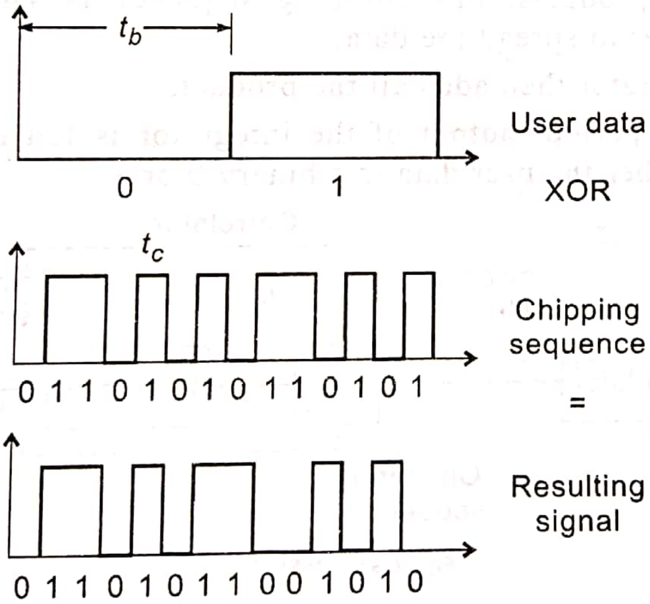

Fig. 2.29 : Spreading of Signal Using DSSS

- The wireless LAN complying with the IEEE 802.11 standard uses the barker code 10110111000.

- **DSSS Transmitter**
  - *Figure 2.30* shows a typical DSSS transmitter.
  - User data is first XORed with the chipping sequence to obtain the spread signal.
  - This signal is then converted to an analog baseband signal by digital modulation.
  - The baseband signal is then subject to analog modulation and transmitted.

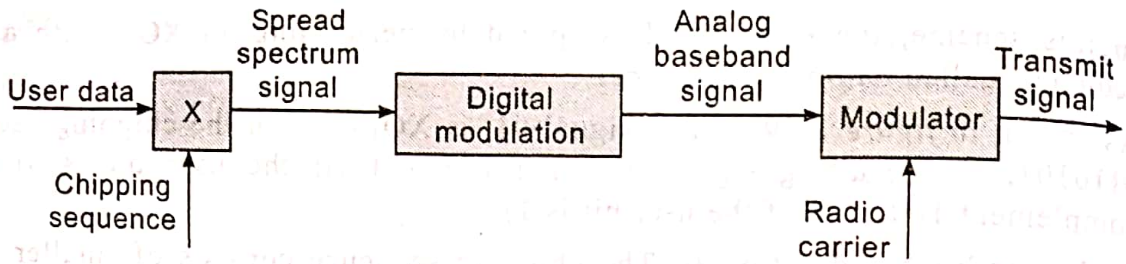

Fig. 2.30 : DSSS Transmitter

➤ **DSSS Receiver**

- The DSSS receiver is comparatively more complex than the transmitter (refe *figure 2.31*).
- The received signal is first converted to baseband signal by the demodulato Additional mechanisms also need to be applied as the data may be distorte due to noise and multipath propagation.
- The low pass filtered signal is now applied to a correlator; the correlato performs two steps which need precise synchronization with the sender.
  - ♦ Firstly, the signal is once again XORed with a chipping sequence t generate products; this chipping sequence is same as that used by th transmitter to spread the data.
  - ♦ The integrator then adds all the products.
- For each bit period, output of the integrator is fed to the decision unit tha decides whether the user data is a binary 0 or 1.

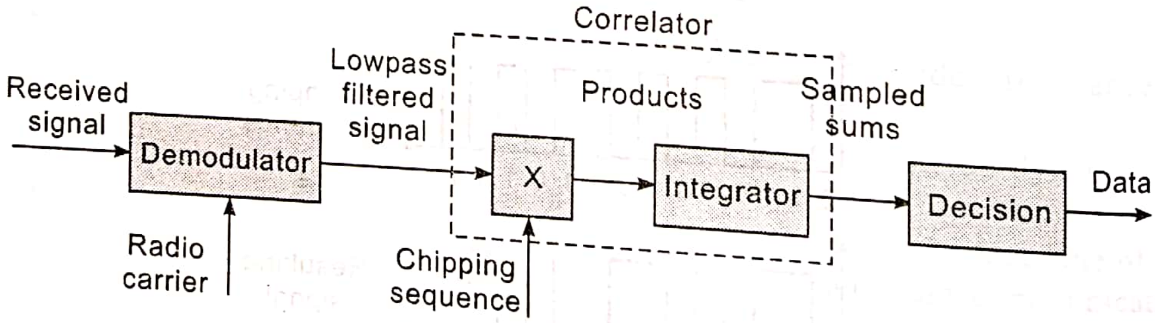

Fig. 2.31 : DSSS Receiver

➤ As an example consider the following case,

- The user data 01 is spread using a barker code 10110111000 to generate th spread spectrum signal 10110111000 01001000111. This spread signal is the modulated and transmitted by the transmitter.
- At the receiver's side, this signal is first demodulated, and then, bit wis XORed with the same barker code.
- Ideally, the sum of the products will be equal to 0 for the first user bit and it'l be equal to 11 for the second user bit.
- Thus, the decision unit can deduce that the first sum corresponds to a binary 0, whereas the second sum corresponds to a binary 1.
- However, in a real life scenario, due to distortion some of the bits of the spread

signal may be flipped. Let's assume that due to this, the sum of the products for the first bit is 2 and for the second bit is 9.

- In such a case, the receiver can map all the sum values below 4 to a binary 0 and all the values above 7 to a binary 1.
- Thus, even in case of distortion the actual data can be recovered.

➤ **Rake Receiver** (refer *figure 2.32*)

- It provides a solution to the problem of multipath propagation.
- It uses 'n' correlators for the 'n' strongest paths.
- Each correlator is synchronized to the transmitter plus the delay on that path.
- The output of each correlator is multiplied with a suitable weighing factor and fed to the decision unit.
- Decision unit takes the decision based on combined output of all the correlators.
- Thus, DSSS system can actually benefit from multipath propagation.

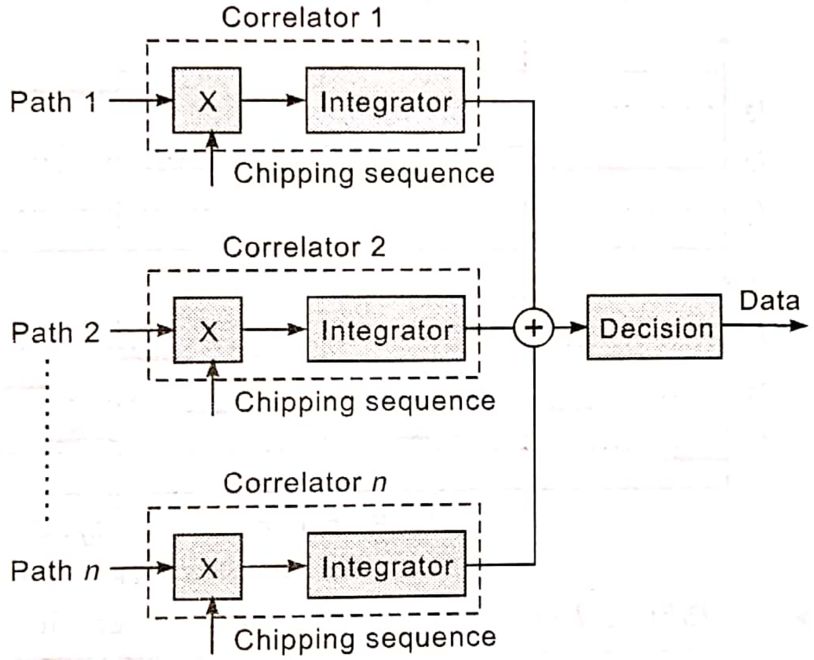

Fig. 2.32 : Rake Receiver

➤ **Advantages of DSSS**

- Reduces frequency selective fading.
- In case of cellular systems, several base stations can use the same frequency for transmission.
- A soft handover is possible using DSSS.

➤ **Disadvantages of DSSS**

- The overall system is complex to implement.
- Precise power control required.
- Synchronization required between the sender and the receiver.

2.7.2 Frequency Hopping Spread Spectrum (FHSS) (V.IMP)

Q.1. *Draw the block diagram of FHSS transmitter and receiver. Differentiate between slow hopping and fast hopping.* **[May 06, May 07, May 08, May 10] (10 M)**

➤ In this method, the total available bandwidth is split into many channels of smaller bandwidth along with guard spaces between the channels.

➤ This system implements a combination of FDM and TDM, thus, the transmitter and the receiver stay on one of the channels for a certain period of time and then hop to another channel.

- The time spent on a channel at a particular frequency is called as the *dwell time*.
- The pattern of channel usage is called as *hopping sequence* and it has two types as shown in *figure 2.33*.

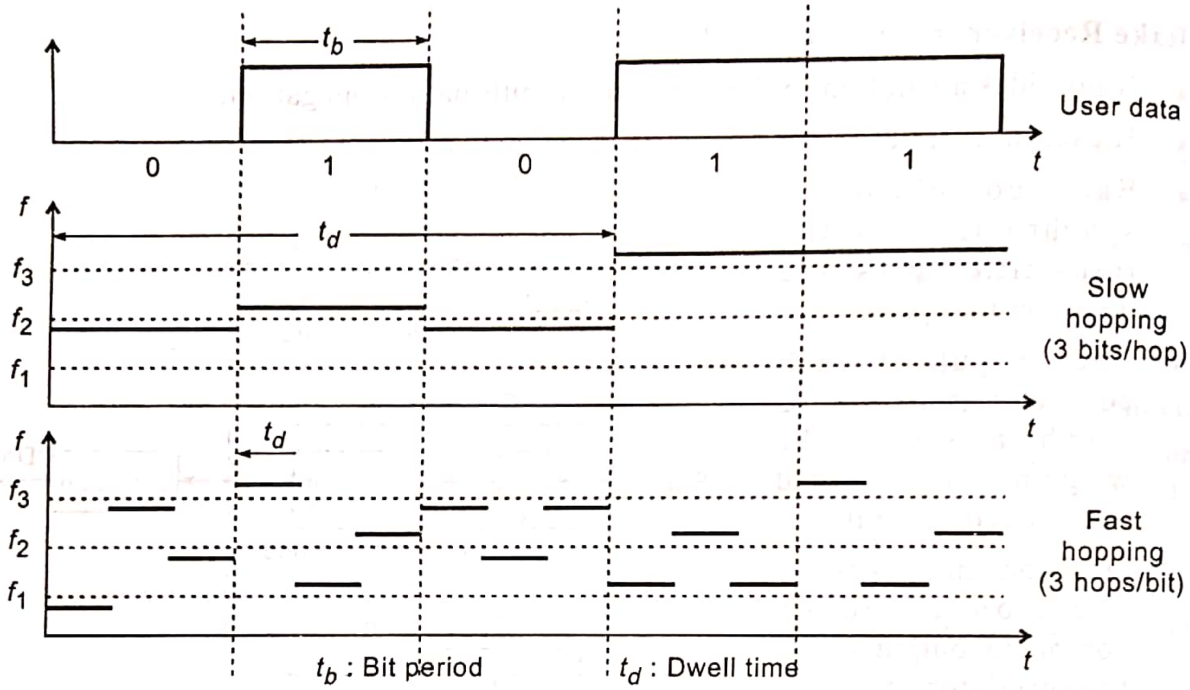

Fig. 2.33 : Slow Hopping and Fast Hopping

- *Table 2.1* shows the difference between slow and fast hopping.

Sr. No.	Slow Hopping	Fast Hopping
(1)	Several user bits are transmitted at the same frequency. Therefore, $t_d > t_b$.	Several frequencies may be used to transmit a single user bit. Therefore, $t_d < t_b$.
(2)	Provides lesser resistance to narrowband interference.	Better resistance against narrow-band interference and frequency selective fading as compared to slow hopping.
(3)	Lower security as compared to fast hopping.	Better security as compared to slow hopping.
(4)	Slow hopping systems are cheaper and have relaxed tolerances.	Comparatively costlier with smaller tolerances.
(5)	Very tight synchronization is not required.	Very tight synchronization is required.
(6)	Can be used by GSM.	Used by Bluetooth. (1600 hops/sec).

Table 2.1 : Difference Between Slow Hopping and Fast Hopping

FHSS Transmitter

- The simplified block diagram of FHSS transmitter is shown in *figure 2.34*.
- User data is first converted to a narrowband signal using digital modulation (FSK or BPSK).
- Frequency hopping is then performed using hopping sequence. Hopping sequence is applied to the frequency synthesizer that generates the corresponding carrier frequencies.
- Analog modulation is then applied to shift the narrowband frequency by the carrier frequency.
- Thus, the spread signal is generated.
- The hopping sequences used by various transmitters should have low cross-correlation among them.

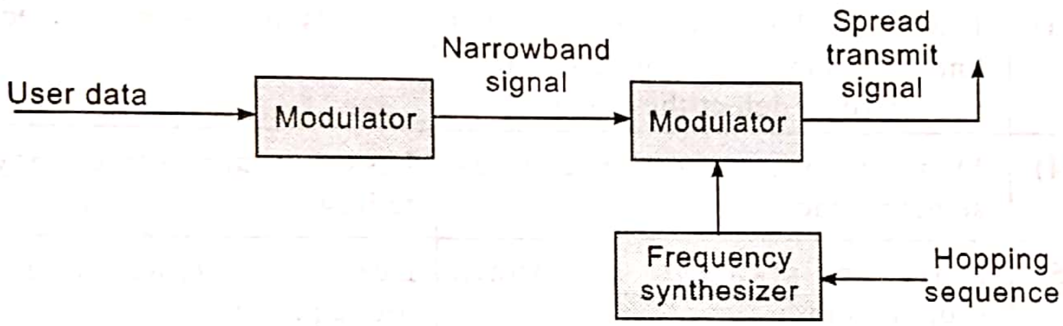

Fig. 2.34 : FHSS Transmitter

FHSS Receiver

- As shown in *figure 2.35*, reverse process needs to be applied at the receiver.
- The received signal is first subject to a demodulation process to generate narrowband signal. The same hopping sequence used to spread the data needs to be regenerated at the receiver and then applied to the frequency synthesizer.
- The narrowband signal is then demodulated again to get the user data.

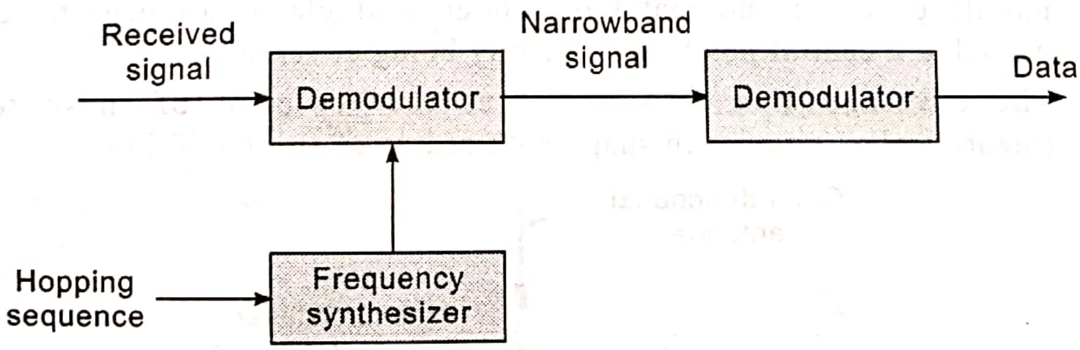

Fig. 2.35 : FHSS Receiver

Advantages of FHSS

- Spreading of signals is simpler.
- Frequency selective fading and interference limited to short period only.
- Uses only a small portion of the total bandwidth at any time.

Disadvantages of FHSS

- Not as robust as DSSS.
- Signals are easier to detect, thus, lower security.

2.7.3 Comparison Between DSSS and FHSS (IMP)

➤ *Table 2.2* shows a comparison between DHSS and FHSS.

Sr. No.	DSSS	FHSS
(1)	Implementation is complex.	Simple to implement.
(2)	At any time, it uses all of the total available bandwidth.	It uses only a small portion of the available bandwidth at any time.
(3)	It provides better security, without knowing the spreading code it is very hard to detect the signal.	Signals are easier to detect.
(4)	More resistant to frequency selective fading.	Less resistant to frequency selective fading.
(5)	More resistant to multipath propagation.	Less resistant to multipath propagation.

Table 2.2 : Comparison Between DSSS and FSSS

2.8 Cellular Systems

2.8.1 Frequency Reuse (V.IMP)

Q.1. What do you mean by frequency reuse concept ? [May 09, Dec. 11] (5 M)

➤ **Need for Frequency Reuse**

- In the first generation of mobile phone systems only large cities received mobile coverage and that too through a single high-power tower which is placed at a central position is the city being covered.
- The coverage area also called as the footprint of these towers was (theoretically) circular in shape with radius of around 50 km.

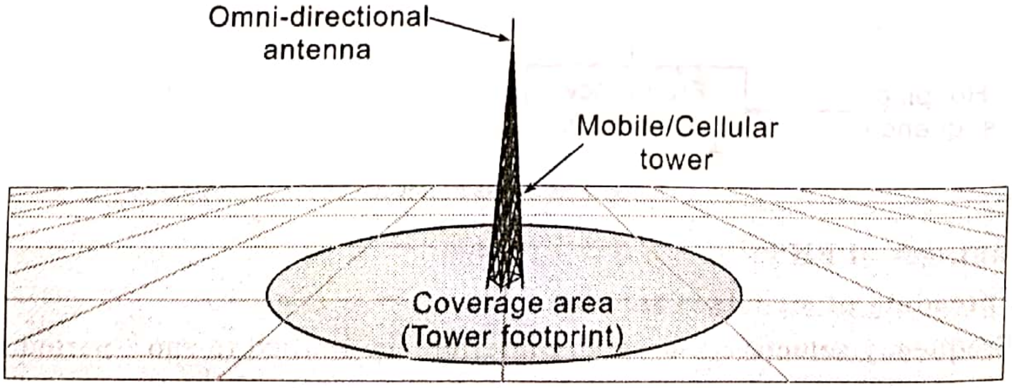

Fig. 2.36 : 1G System Coverage