Code Division Multiple Access (CDMA)

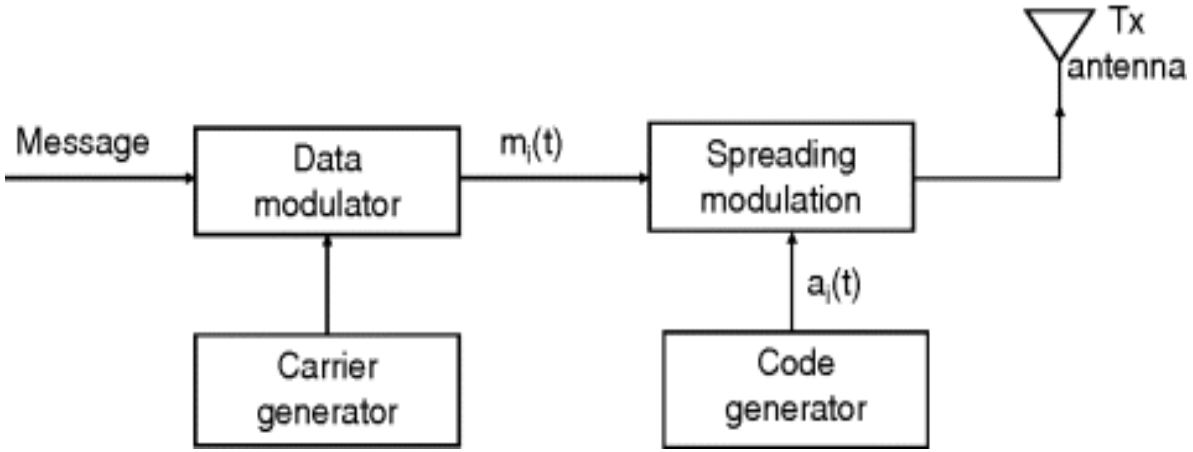
Introduction

- The entire bandwidth of the transponder is used simultaneously by multiple Earth stations at all times.
- Allows multiple Earth stations to access the same carrier frequency and bandwidth at the same time
- Each transmitter spreads its signal over the entire bandwidth, which is much wider than that required by the signal otherwise.
- Multiply the information signal, which has a relatively lower bit rate, by a pseudorandom bit sequence with a much higher bit rate
- Interference between multiple channels is avoided as each transmitter uses a unique pseudorandom code sequence
- Receiving stations recover the desired information by using a matched decoder that works on the same unique code sequence used during transmission

- Assume that the message signal is a PCM bit stream.
- Each message bit is combined with a predetermined code bit sequence. This predetermined code sequence of bits is usually a pseudorandom noise (PN) signal.
- The bit rate of the PN sequence is kept much higher than the bit rate of the message signal. This spreads the message signal over the entire available bandwidth of the transponder.
- It is because of this reason that this technique of multiple access is often referred to as spread spectrum multiple access (SSMA).
- The spread spectrum operation enables the signal to be transmitted across a frequency band that is much wider than the minimum bandwidth required for the transmission of the message signal.
- The PN sequence bits are often referred to as ‘chips' and their transmission rate as the ‘chip rate'. The receiver is able to retrieve the message addressed to it by using a replica of the PN sequence used at the transmitter, which is synchronized with the transmitted PN sequence.

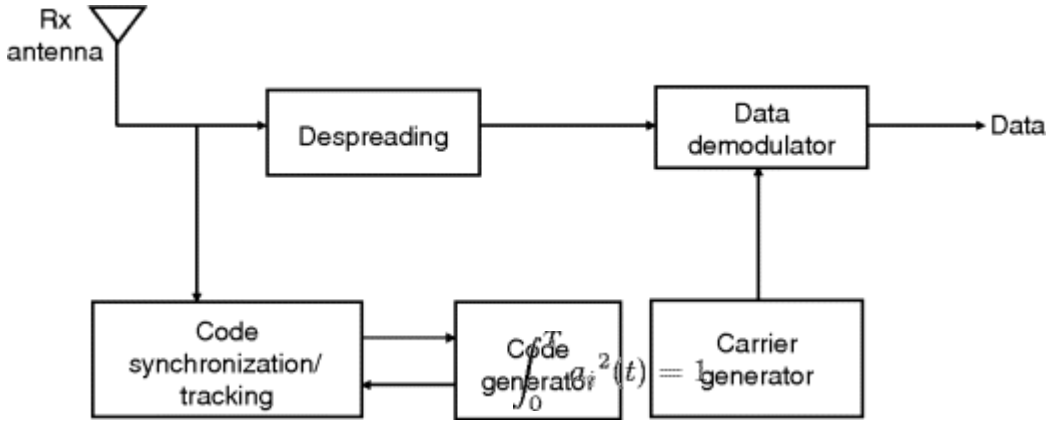
- CDMA uses direct sequence (DS) techniques to achieve the multiple access capability.
- In this, each of the *N* users is allocated its own PN code sequence. PN code sequences fall into the category of orthogonal codes.
- Cross-correlation of two orthogonal codes is zero, while their auto-correlation is unity. This forms the basis of each of the *N* stations being able to extract its intended message signal from a bit sequence that looks like white noise.

DS-CDMA TRANSMISSION



- The transmitter generates a bit stream by multiplying in the time domain the message bit stream $m_i(t)$ and the code information $a_i(t)$.
- Multiplication in the time domain is convolution in the frequency domain. Therefore, the product of $m_i(t)$ and $a_i(t)$ produces a signal whose spectrum is nothing but convolution of the spectrum of $m_i(t)$ and the spectrum of $a_i(t)$.
- Also, if the bandwidth of the message signal is much smaller than the bandwidth of the code signal, the product signal has a bandwidth approaching that of the code signal.
- If the message signal is digital in nature the message signal will be directly multiplied by the code signal.

DS-CDMA RECEPTION



The receiver in this case generates a code signal $a_i(t)$ synchronized with the received message.

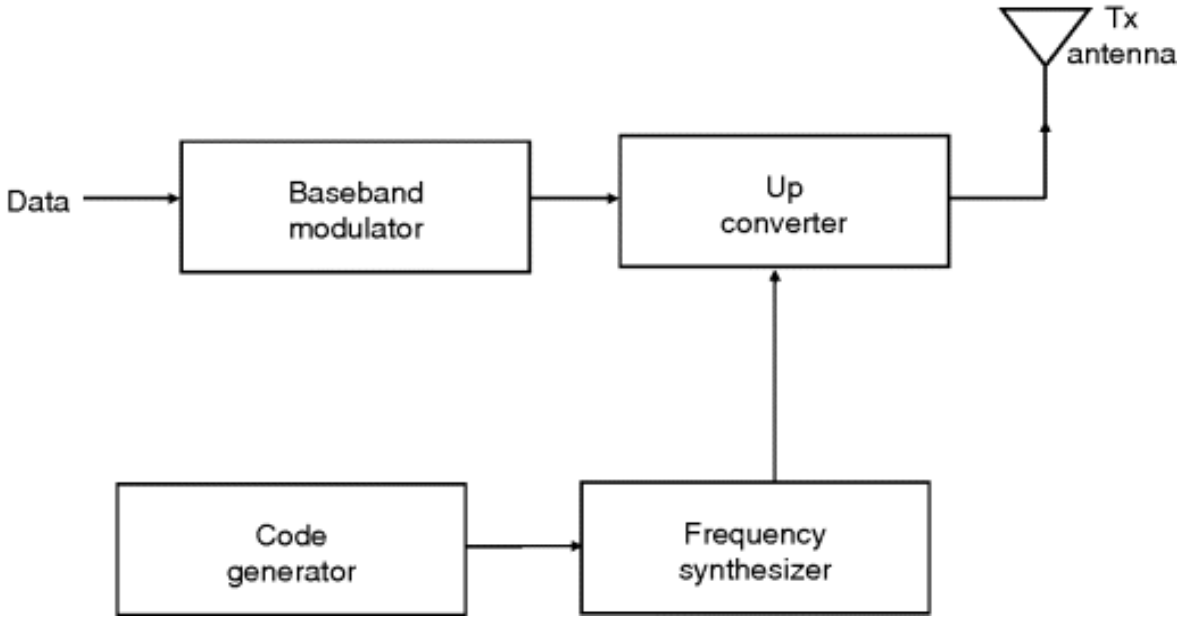
$$\frac{}{[a_i^2(t)]}[m_i(t)] + \sum_{i=1 j\neq i}^{N} \frac{}{[a_i(t)][a_j(t)]}[m_j(t)]$$

$$\int_0^T a_i{}^2(t) = 1 \qquad \int_0^T [a_i(t)][a_j(t)] = 0 \quad \text{for } i \neq j$$

FREQUENCY HOPPING CDMA (FH-CDMA) SYSTEM

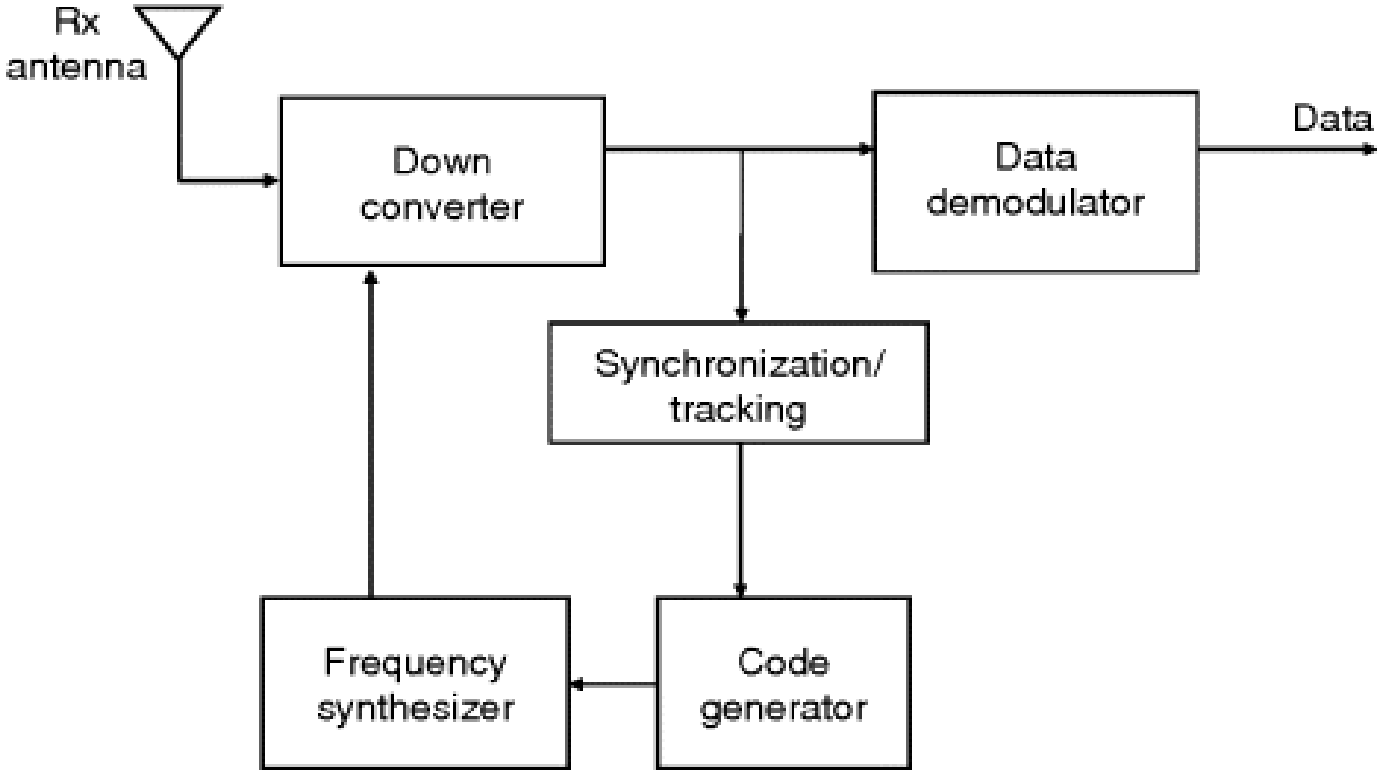
- In the case of a frequency hopping CDMA (FH-CDMA) system, the carrier is sequentially hopped into a series of frequency slots spread over the entire bandwidth of the satellite transponder.
- The transmitter operates in synchronization with the receiver, which remains always tuned to the frequency of the transmitter.
- The transmitter transmits a short burst of data on a narrowband, then tunes to another frequency and transmits again. The transmitter thus hops its frequency over a given bandwidth several times per second, transmitting one frequency for a certain period of time, then hopping to another frequency and transmitting again.
- This is achieved by using a frequency synthesizer whose output is controlled by a pseudorandom code sequence. The pseudorandom code sequence decides the instantaneous transmission frequency.

FH-CDMA - TRANSMITTER



FH-CDMA Receiver

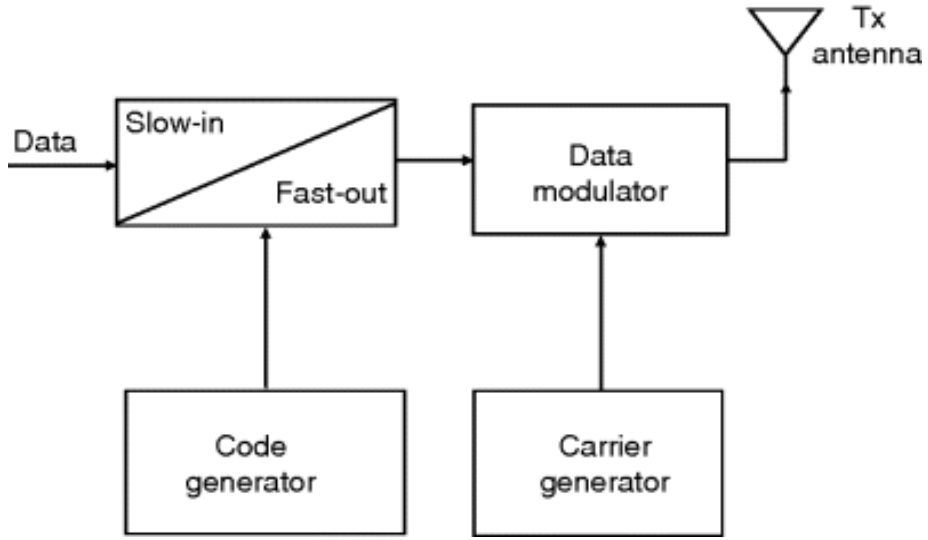
On the receiver side, the data can be recovered by using an identical frequency synthesizer controlled by an identical pseudorandom sequence.

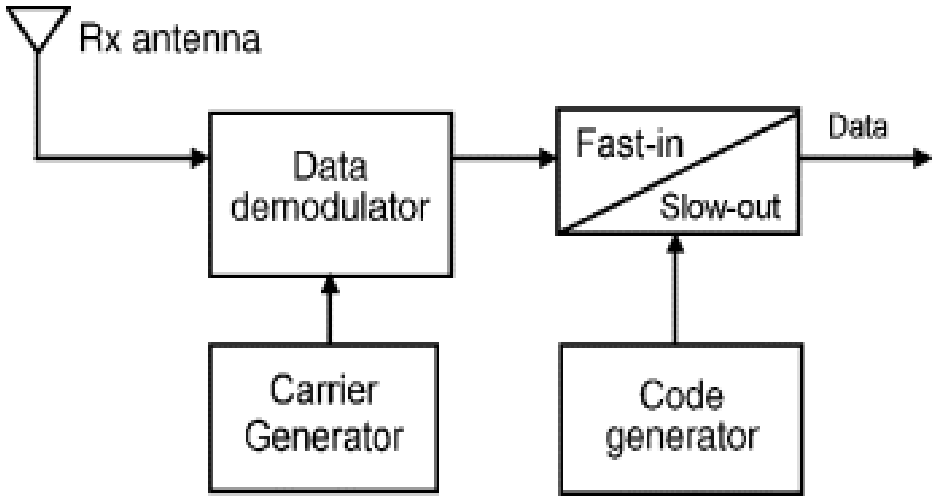


TIME HOPPING CDMA (TH-CDMA) SYSTEM

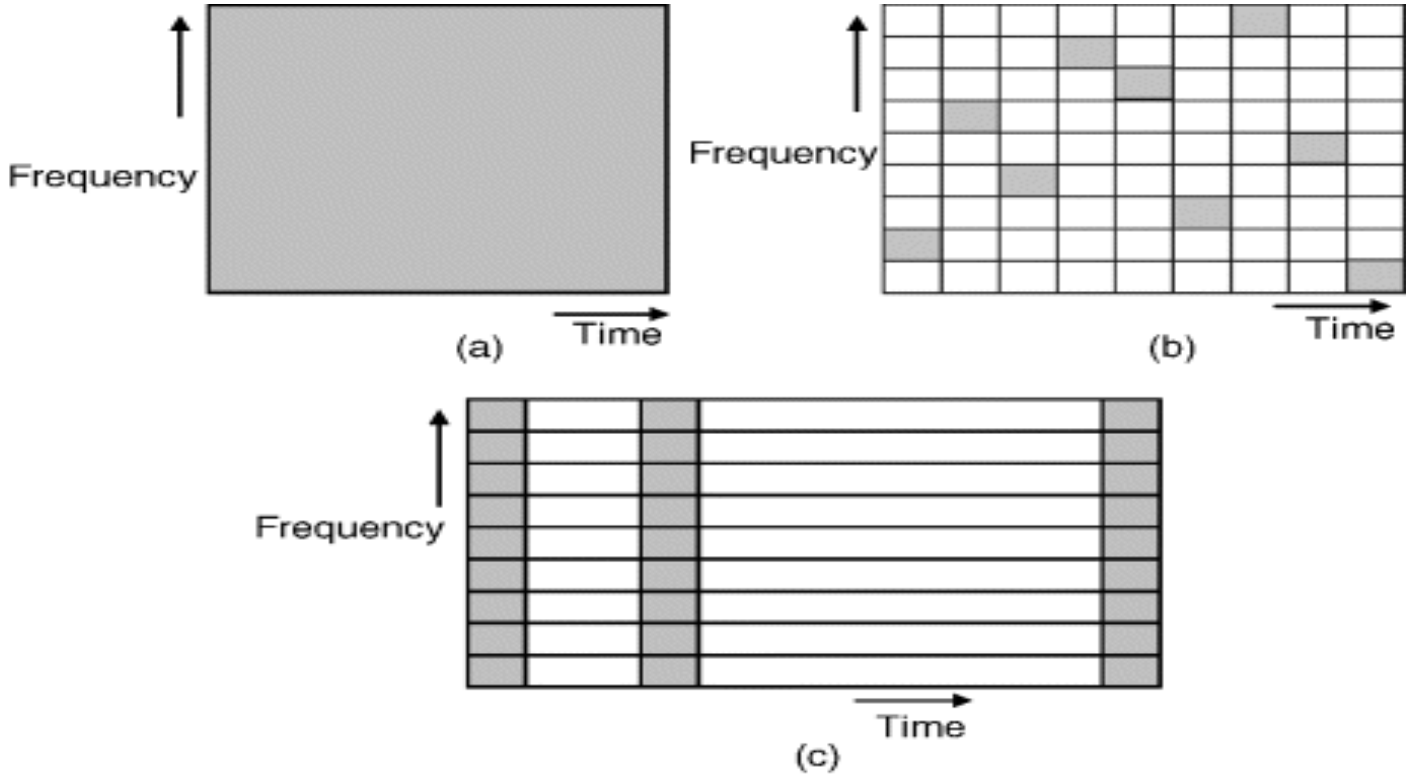
- In the case of the time hopping CDMA (TH-CDMA) system, the pseudorandom bit sequence determines the time instant of transmission of information.
- The signal is transmitted by the user in rapid bursts during time intervals determined by the pseudorandom code assigned to the user.
- A given user transmits only during one of the *M* time slots each frame has been divided into.
- The time slot used by a given user for transmission of data in successive frames depends upon the code assigned to it.
- Since each user transmits its data only during one of the *M* time slots in each frame, the bandwidth available to it increases by a factor of *M*.

TIME HOPPING CDMA (TH-CDMA) SYSTEM





COMPARISON OF DS-CDMA, FH-CDMA AND TH-CDMA SYSTEMS



Reference

- https://learning.oreilly.com/library/view/satellite-technology-principles/9781118636374/c06.xhtml