Spread Spectrum Radio

- Develops information theory principle that signals are best protected from noise by making them look like noise
- Instead of allocating a signal to a narrow channel within a radio spectrum, it spreads the signal over the whole spectrum in a predictable way.
- Security against against snooping
- Security against most forms of noise
- Security against jamming

Two types of spread spectrum

- Frequency hopping spread spectrum
- Direct sequence spread spectrum

- Spread spectrum uses forms of double modulation involving the data, a pseudo-random generator and the RF carrier. The bit-time of the pseudo-random generator is known as a *chip*, and states change at the *chip rate.*

- *Frequency hopping* first uses the pseudo-random generator (an *N*-ary generator) to frequency modulate the carrier and then uses data to modulate the hopping carrier.

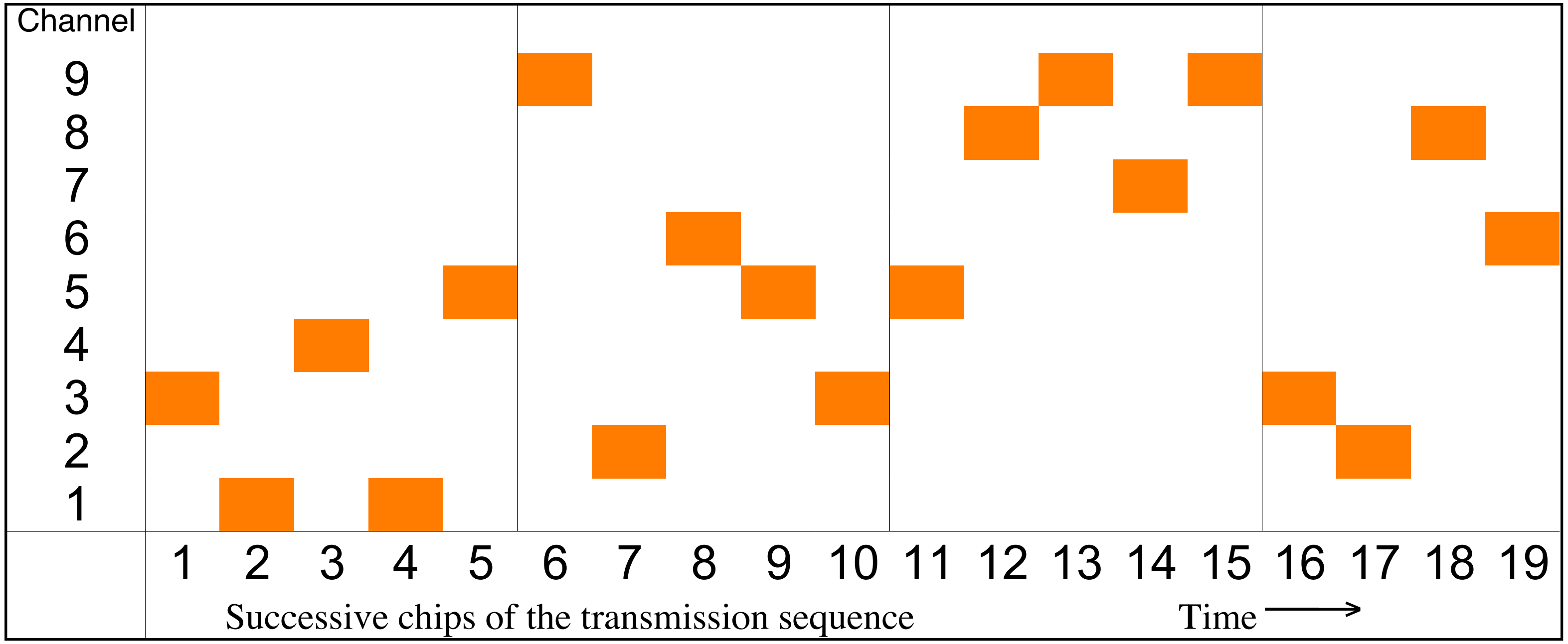
- *Direct sequence* first applies the data to the pseudo-random generator (both binary) and then uses the combination to modulate the rf carrier.

- "Slow Spread Spectrum" has the `chip rate < data rate`, or has several data bits per chip. It is simpler and cheaper but has poorer performance.

- "Fast Spread Spectrum" has the `chip rate > data rate`, or has several chips per data bit. The equipment is more expensive but gives better noise rejection and security.

Frequency Hopping Spread Spectrum

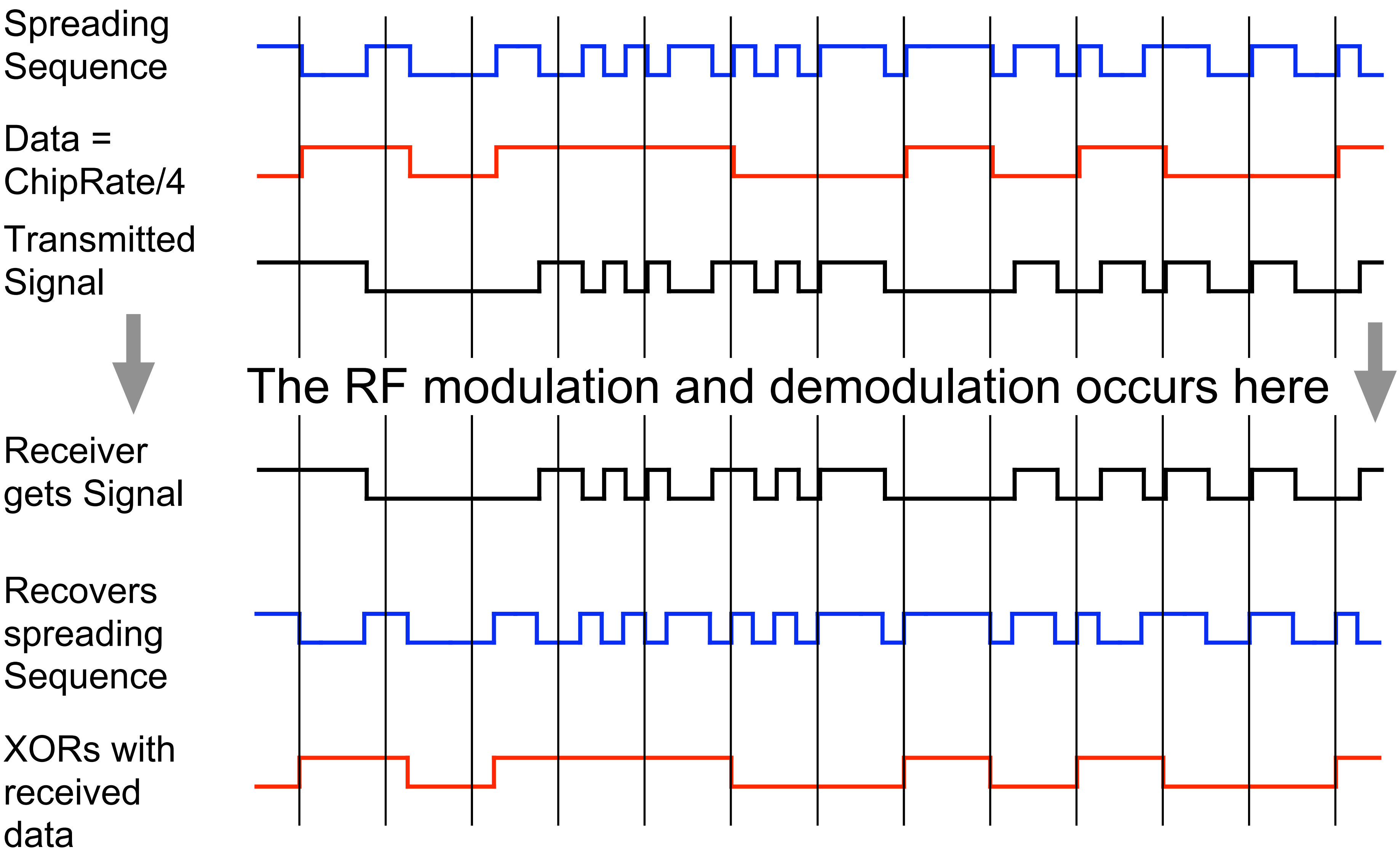
- The spectrum is divided into separate channels (possibly tens or hundreds), usually at a fixed frequency separation.
- The transmission frequency hops among the channels according to a pseudo-random sequence and the data is then modulated onto the hopping frequency; the receiver tracks the transmitter



Direct-Sequence Spread Spectrum

- In direct-sequence spread spectrum the data is first exclusive-ORed with a pseudo-random binary sequence (the "spreading code").
  This is equivalent to modulating the pseudo-random "carrier" with the data – Frequency Shift Keying or FSK.
- The spreading code spreads the radio frequency energy among all of the sidebands, which because of the random code are spread randomly over the available spectrum.
- The data modulation appears as a disturbance to the spreading code distribution.
- The receiver uses a matching spreading code and detects the difference between what is received and what is expected.

Illustration of Direct Sequence Spread Spectrum



Spreading factor

- The number of chips per data bit, N, is known as the spreading factor but is normally called the *processing gain*, written in decibels –
  processing gain (in dB) = $20\log_{10}N$
- If noise is concentrated at a single frequency, it will interfere with only one channel with frequency hopping; when averaged over all channels used for that bit it will be effectively reduced by a factor N, or by $20\log_{10}N$ dB.
- A similar averaging process applies to direct-sequence spread spectrum, with each data bit averaged over N chips; with random noise, spreading a data bit over several chips effectively decorrelates the noise with the same overall effect.
- The spreading factor or processing gain is effectively a factor by which the signal/noise ratio is improved by using spread spectrum.

Multiplexing & Multiple Access Methods

These all allow different communications to use the same “space”, in a very general sense

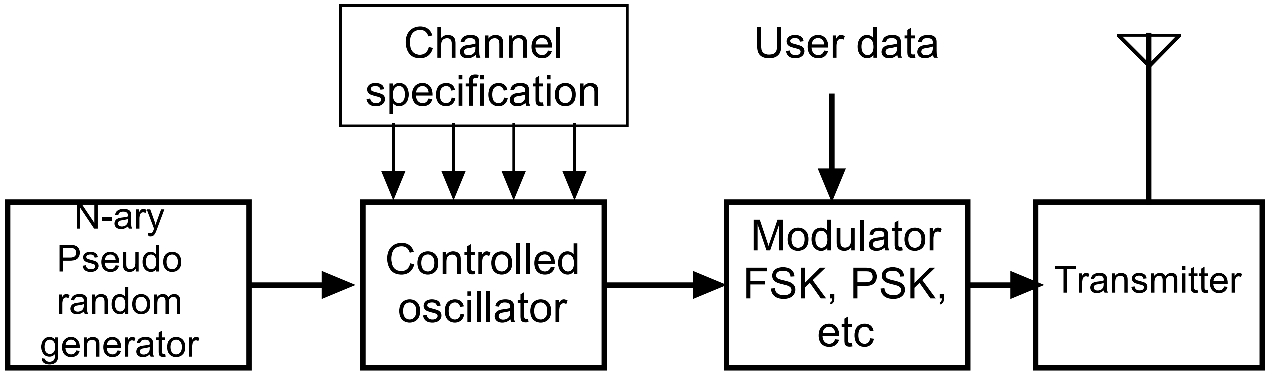
- Frequency division multiplexing – different services allocated to different frequencies, such as radio or TV channels
- Time division multiplexing – different services sent at different times, such TV programs (or sequential packets in data communications)
- Space division multiplexing – different services are physically separated, as on different wires or cables, or physically distant radio transmitters on the same frequency
- Code division multiplexing (CDMA) – different spread spectrum services can use the same bandwidth if they use different spreading codes.

CDMA

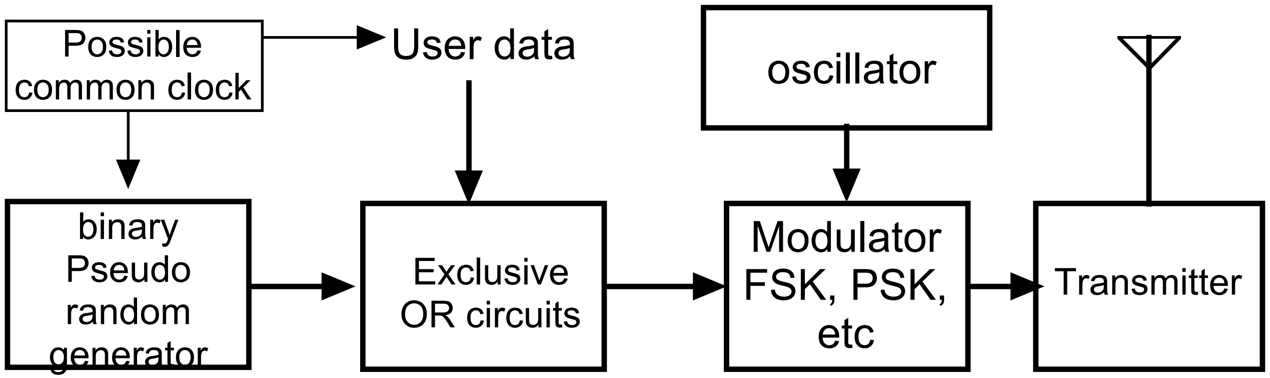
(Stands for Code Division Multiple Access)

- With slow spread-spectrum, collisions appear as bursts of noise, perhaps affecting a few bits.
- With fast spread-spectrum a collision affects only part of a bit. Interfering stations just provide a background noise level which increases with more stations.
- Direct-Sequence spread-spectrum suffers from a form of capture effect in which strong local transmitters overwhelm a weaker signal. The weaker signal is not just there as interfering background – beyond a certain difference in strength it just disappears!
  (A similar effect occurs with FM transmission, given a good receiver!)

Spread Spectrum Transmitters

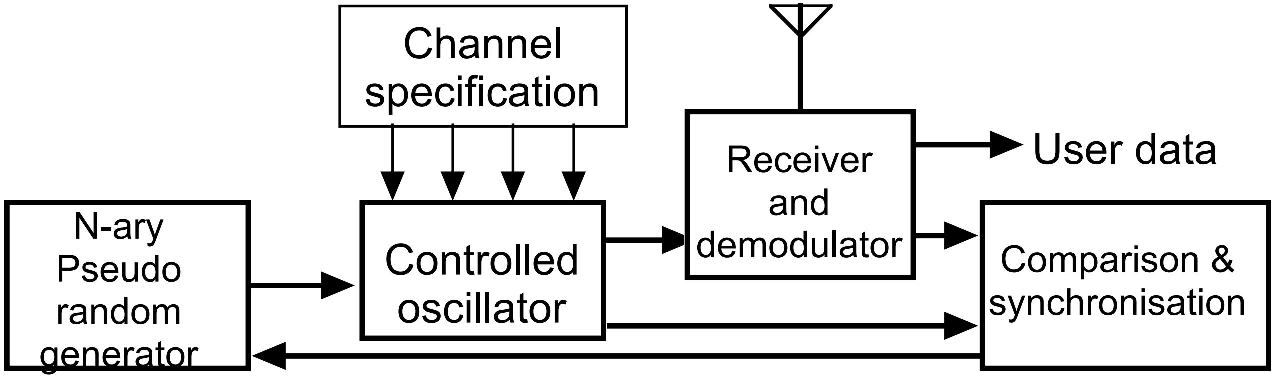


Frequency Hopping Spread Spectrum

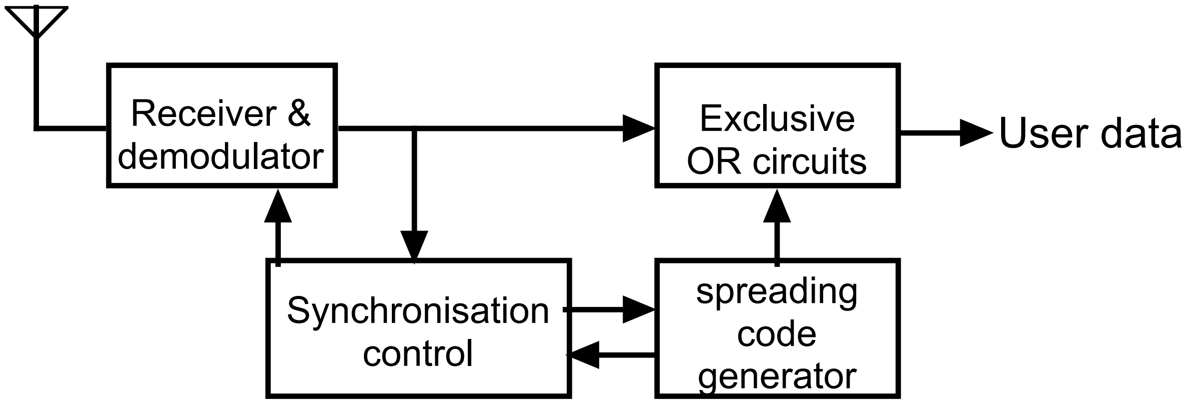


Direct Sequence Spread Spectrum

Spread Spectrum Receivers



Frequency Hopping Spread Spectrum



Direct Sequence Spread Spectrum

- Receivers always work by hunting for a received sequence with the correct hopping or spreading code. They normally rely on very accurate time synchronisation between the receiver.
- A frequency hopping receiver might start with the “time of day” a little earlier than expected and run the hopping clock slightly fast. Eventually the received and expected hops will match and the clocks can synchronise.
- Halsall describes synchronisation of a direct-sequence receiver using a known preamble to each transmitted message.