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COURSE ON BASIC TELECOMMUNICATIONS SCIENCE

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"Spread Spectrum Communications"

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SPREAD SPECTRUM SYSTEMS. (DS & FH).

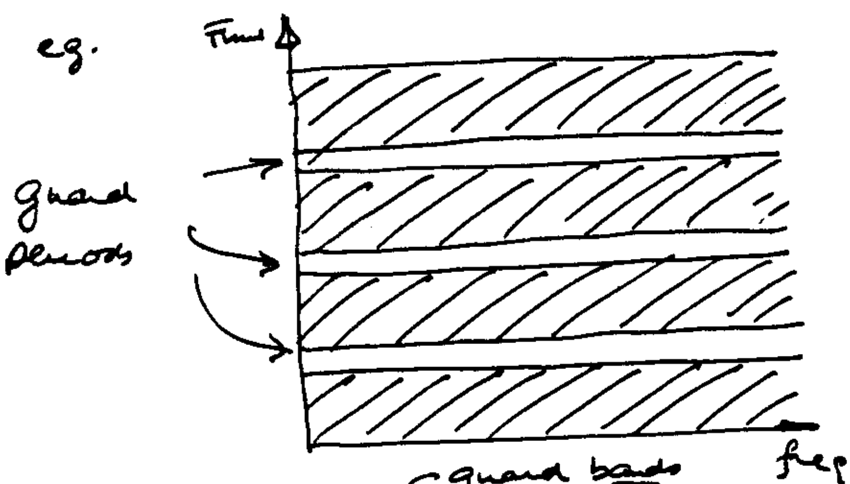
Broadly defined as situations where we spread a signal into a spectrum which is very much larger than the minimum requirement & the mechanism of spreading is quite separate from our signal.

So FM is not considered to be a spread spectrum signal. However it is worth noting here the signal/noise advantage over basic AM is $\propto$ deviation ratio^2. This is in a sense a 'Process Gain'.

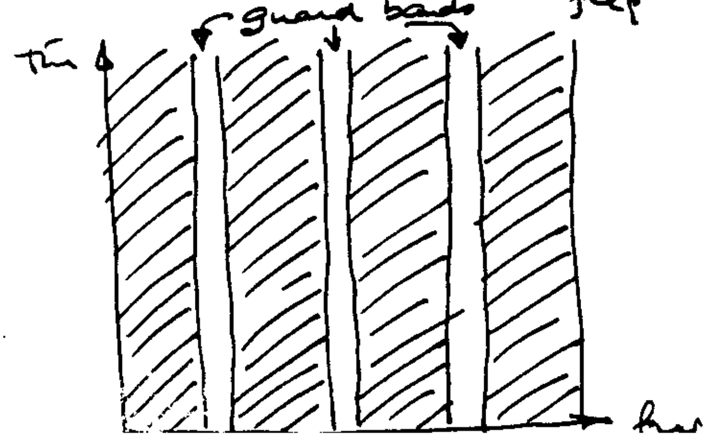
A similar example might spread a single voice channel into many megahertz.

So given a band of frequency it is a function of how you use it

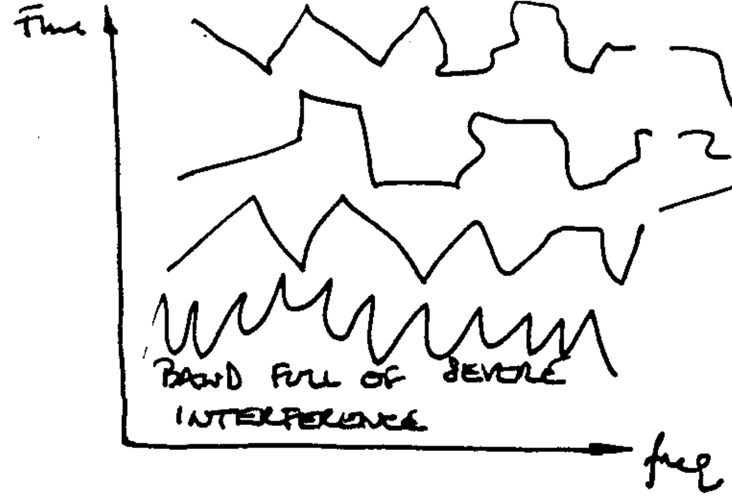
eg.



represents Time Domain Multiplexing — TDM.



represents Frequency Domain multiplexing.



idea of separate, separately coded spread spectrum signals.

- no guard bands
- low power level
- immense coding

Early developments driven by military applications
Only relatively recently that SS techniques are being developed & argued in the open literature.

- again the process is being driven by the developments & ability of digital technologies.

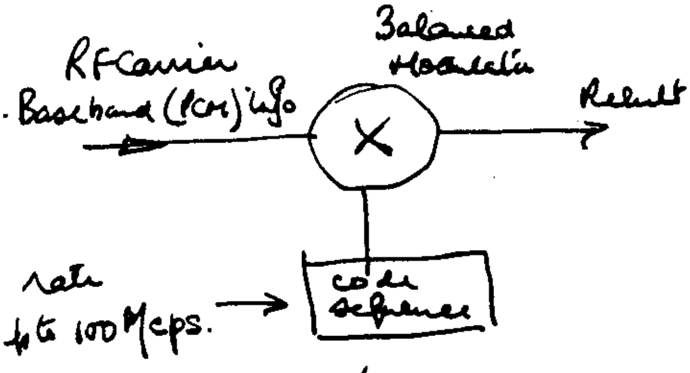
Examples of use:

- Military strategies
- Satellite communication * uplink
- Navigation
- Ranging – GPS (Global Positioning System).

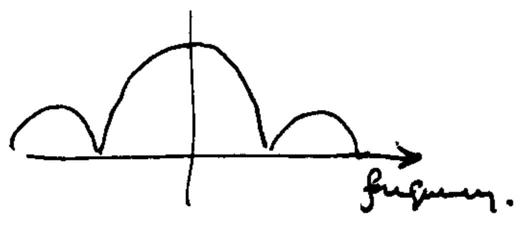
Two main types:

when phase coherence is possible
Effectively use simple PSK ideas.

Called Direct Sequence (DS) } S.S.
or Pseudo Noise (PN)

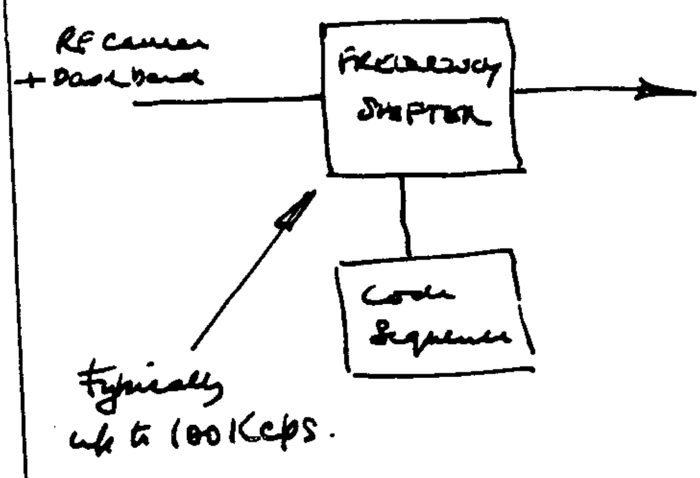


Spectrum typical sinc!



when phase coherence is not available (eg high speed aircraft transmission) we use

FREQUENCY HOPPING (FH)



The Basic code generator clock rate is called the 'CHIP' rate (also equals the hop rate in FH)

Obviously to properly receive the baseband information the receiver must also know the same code which must first be synchronised with the transmitter & then multiplied.

Whole basis of Spread spectrum is based on Shannon's theorem of channel capacity

$$C = B \log_2 \left(1 + \frac{S}{N}\right) \qquad \text{where } \frac{S}{N} = \frac{\text{signal}}{\text{noise}}.$$

(Channel Capacity bits/sec) Bandwidth.

$$\therefore \frac{C}{B} = 1.44 \log_e \left(1 + S/N\right)$$

$$= 1.44 \left\{ \frac{S}{N} - \frac{1}{2}\left(\frac{S}{N}\right)^2 + \frac{1}{3}\left(\frac{S}{N}\right)^3 - \cdots \right\}.$$

If S/N very small eg < 0.1

then $\frac{C}{B} \simeq 1.4 \frac{S}{N}$. ie $\frac{S}{N} \propto \frac{1}{B}$.

So that increasing B allows us to <u>decrease</u> $\frac{S}{N}$.

eg if $\frac{S}{N} = \frac{1}{100}$ & $C = 3000$ bits/sec $B_{\text{needed}} = 208$ KHz.

We define a Process Gain $= \frac{\text{Bandwidth (GF)}}{\text{Rate of info}}$ eq $\frac{208}{3} = 18.4$dB

The protection we have from interfering signals is defined by

the Jamming Margin $=$ Process Gain $- \left[\text{Loss}_{\text{system}} + \left(\frac{S}{N}\right)_{\text{out}}\right]$

For an example $= 18.4 - [2 + 6]$ might be typical figures

$= 10.4$

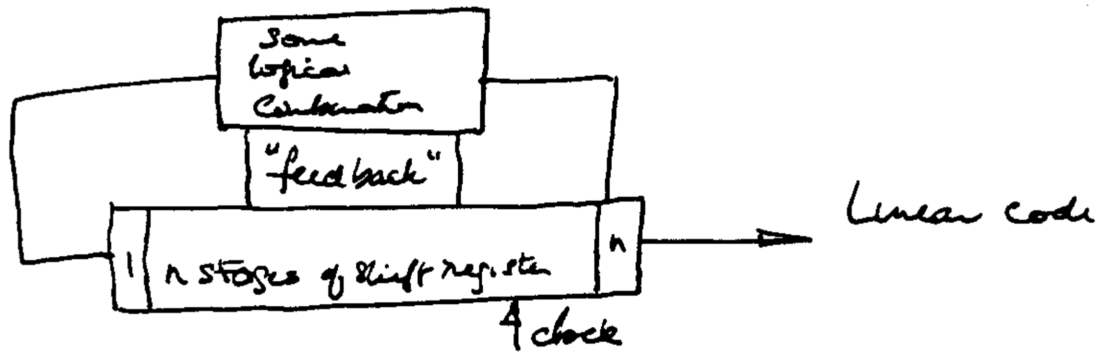
So if $\frac{\text{interfering signal}}{\text{desired}} > 10.4$ <u>no</u> chance.

Narrowband interference is generally not a problem

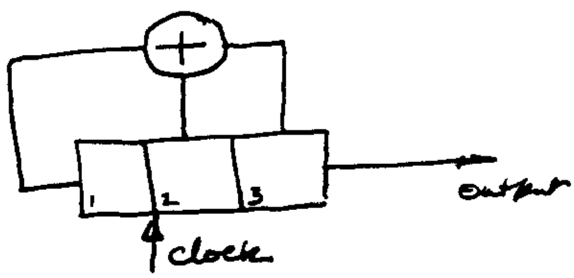
Generating the coded sequence

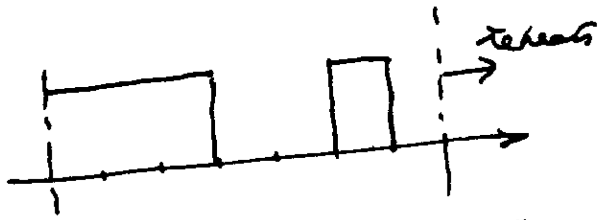
Most common most useful is the 'MAXIMAL' sequence generated by a shift register

In general



Simple example 3 stage case:





Start off (say) with all full 1's –

Shift registers			clock result
1	1	1	1
0	1	1	1
0	0	1	1
1	0	0	0
0	1	0	0
1	0	1	1
1	1	0	0
1	1	1	repeats

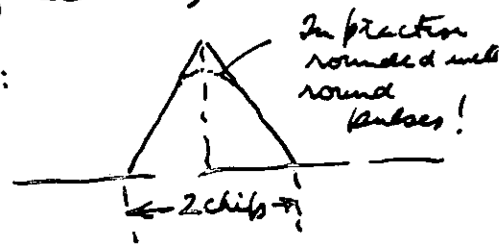
So length of sequence is $2^n - 1$

It will contain $\frac{2^n}{2}$ 1's & $\frac{2^n}{2} - 1$ 0's !

which are as near statistically DC component is small.

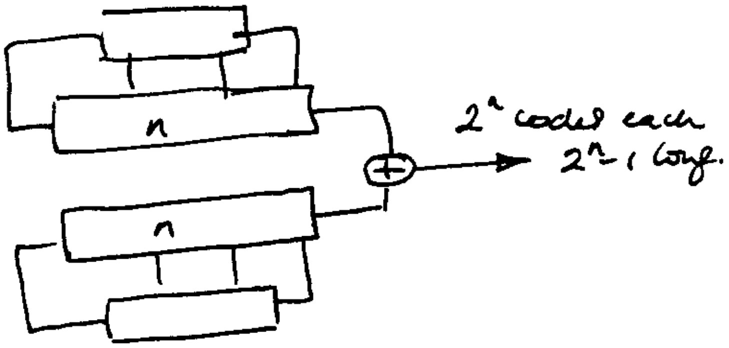
Typically use a 10 stage shift register → 1023 chip maximal code.

Maximal sequences have the important property that they correlate exactly (remember convolution) & give:



Easy to generate ...

eg



Example of GPS operation (see diagram)

Some References

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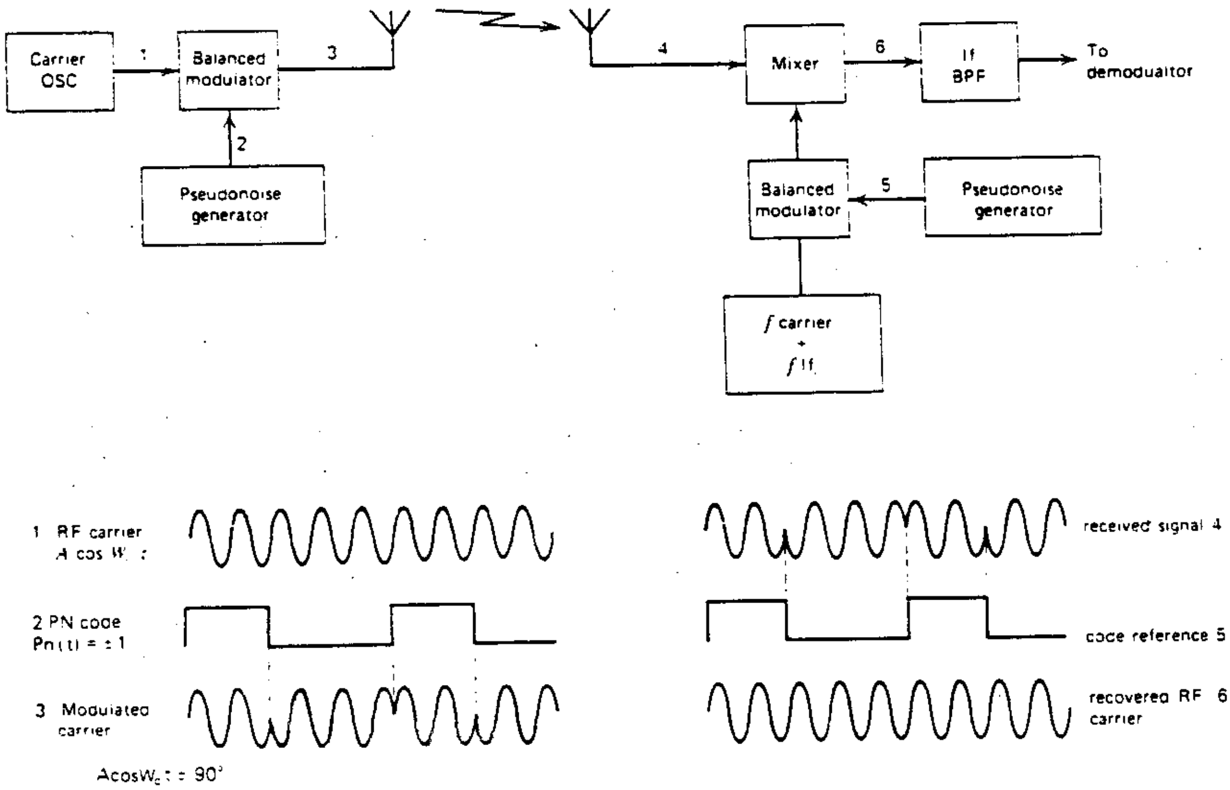


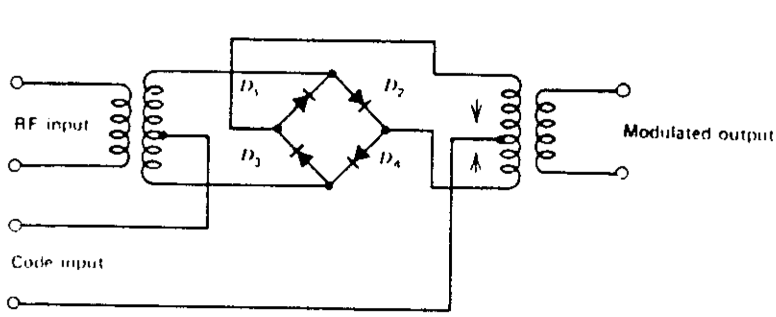
Figure 2.3 Overall direct sequence system showing waveforms.

Balanced modulator
very commonly available
up to > 100 MHz.

$\omega_c t$ → (Bm) → AB cos $\omega_c t$ cos $\omega_m t$

$B\omega_m t$

theoretically
no carrier
practically 20-60 dB down.



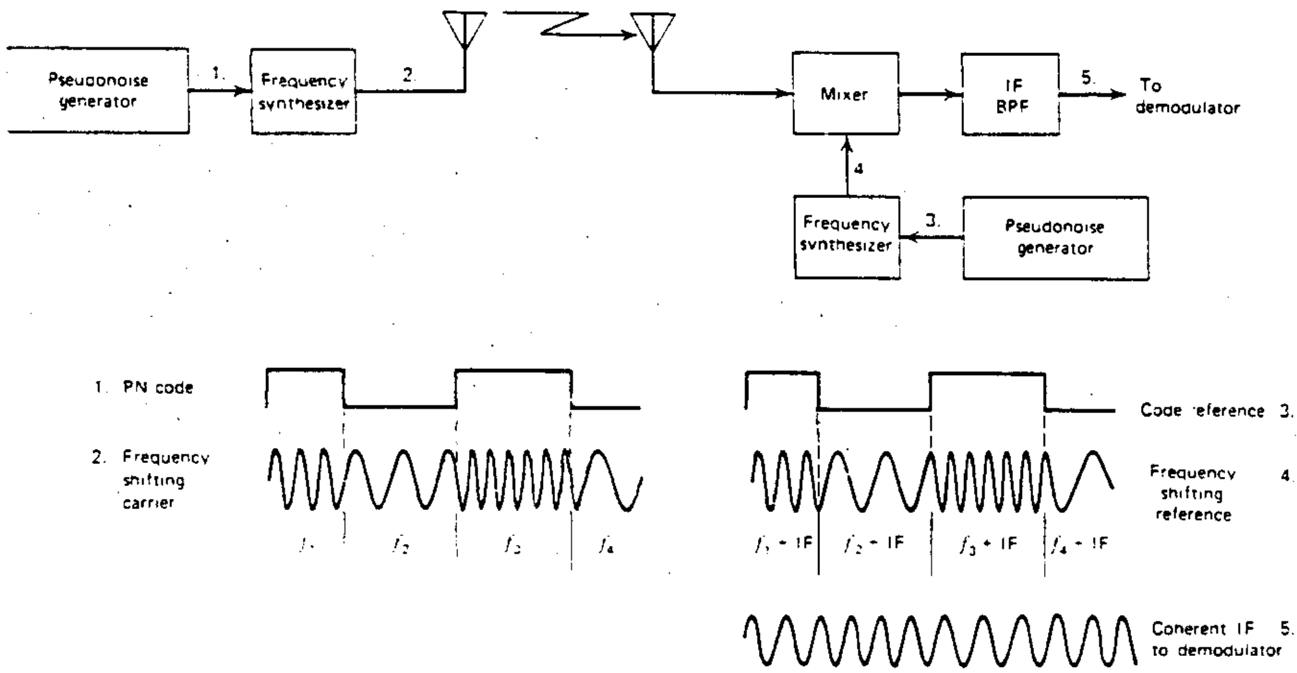


Figure 2.12 Basic frequency hopping system with waveforms.

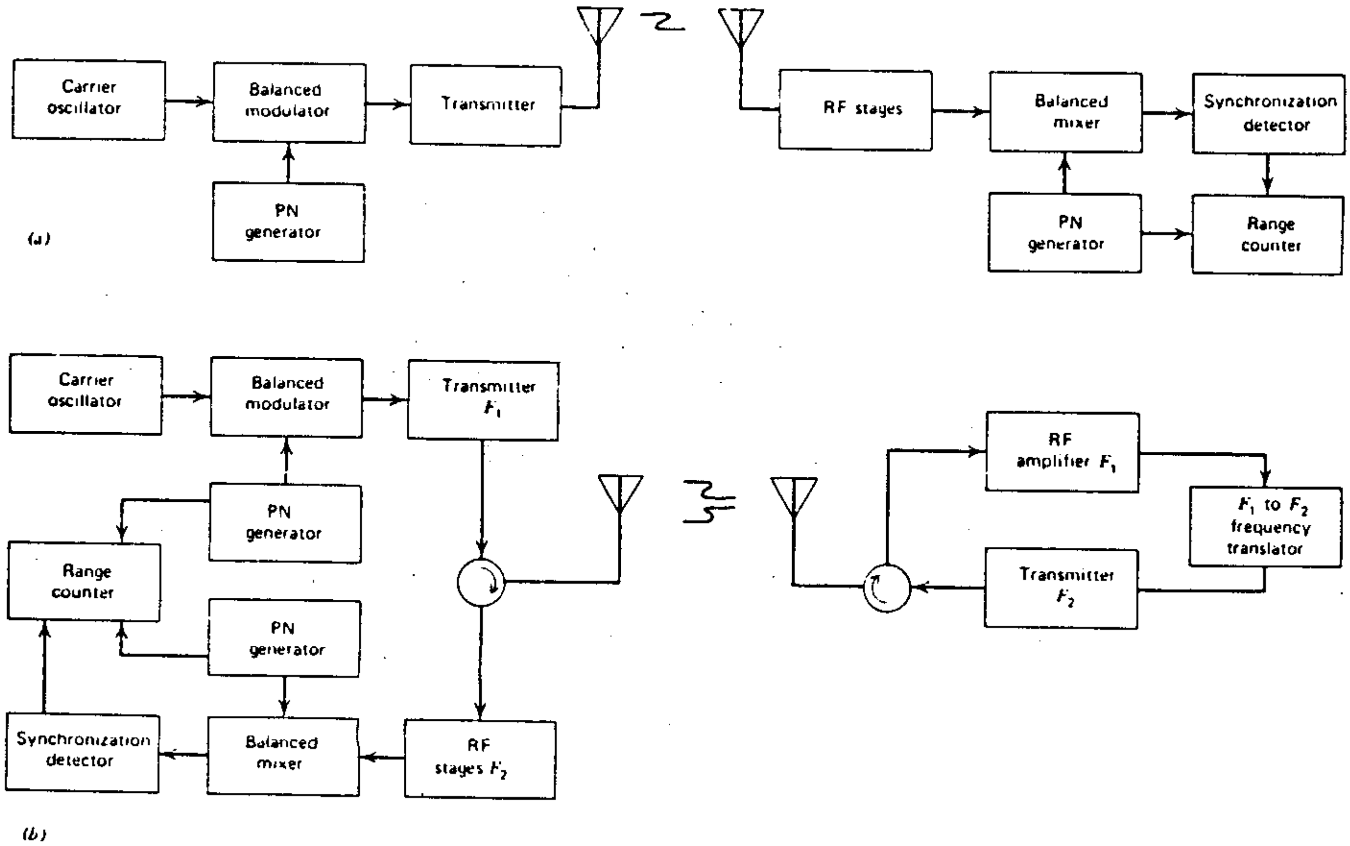


Figure 8.1 Simple direct sequence ranging systems: (*a*) transmit–receive ranging system; (*b*) duplex ranging system.

Short code (clear access or C/A):

- 1.023 Mcps
- 1023 chips long
- Gold codes
- period, 1.0 msec

Long code (protected or P):

- 10.23 Mcps
- one week long
- 6.19×10^{12} chips
- mildly nonlinear code

Modulation:

- 1575 MHz
  - *I* carrier, C/A code
  - *Q* carrier, P code (suppressed 3 dB)
- 1227 MHz
  - P code only

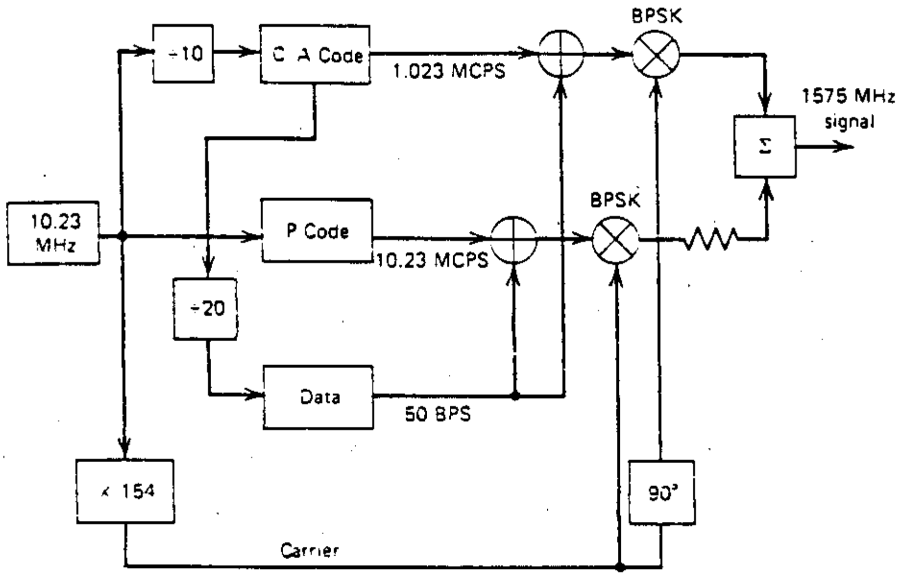


Figure 9.9 GPS modulator configuration. (L₁ signal)

1. A long code (one week repetition period) biphase modulated 1227 MHz signal.
2. A long code (same code) biphase modulated signal at 1575 MHz (← PROTECTED CODE.)
3. A short code (1023 chip Gold code) biphase modulated signal on an orthogonal carrier at 1575 MHz.