Code Division Multiple Access (CDMA)

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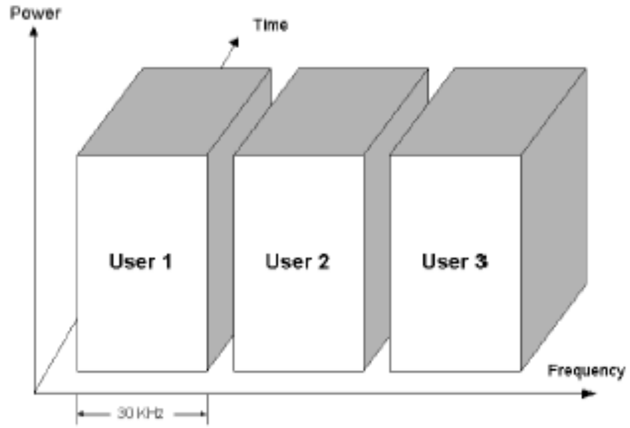
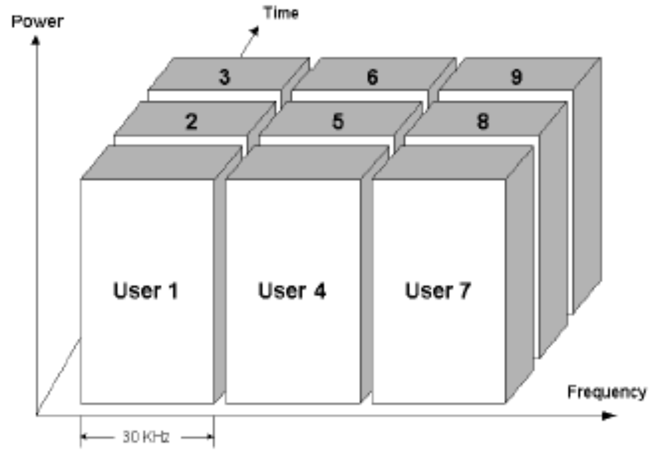
What's the Best Technique?

- In The Beginning, there was Frequency Division Multiple Access (FDMA).
  - ➢ Simple and effective
  - ➢ Poor flexibility, frequency reuse, high-Q RF filters
- Then, TDMA was popular
  - ➢ Better for digital than FDMA
  - ➢ Still with weaknesses, inc. synchronization, poor freq. reuse, equalization

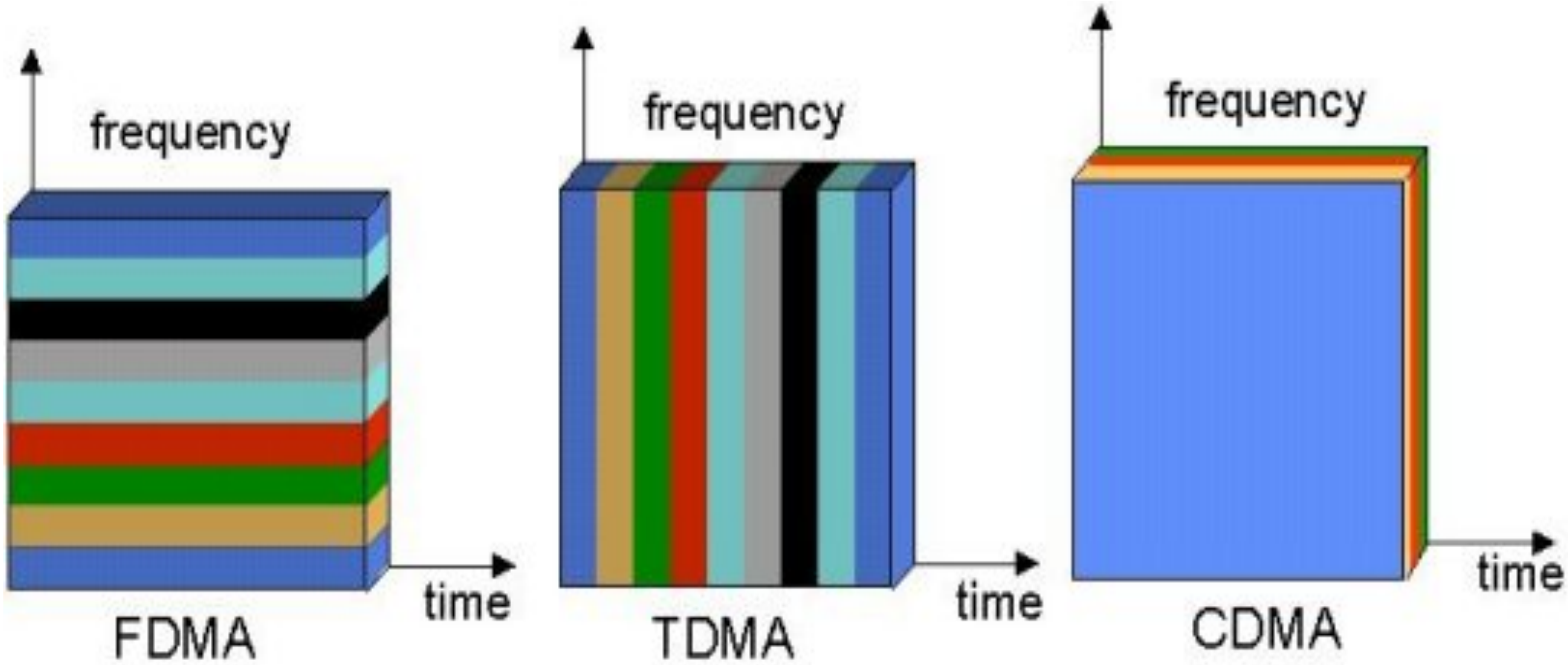


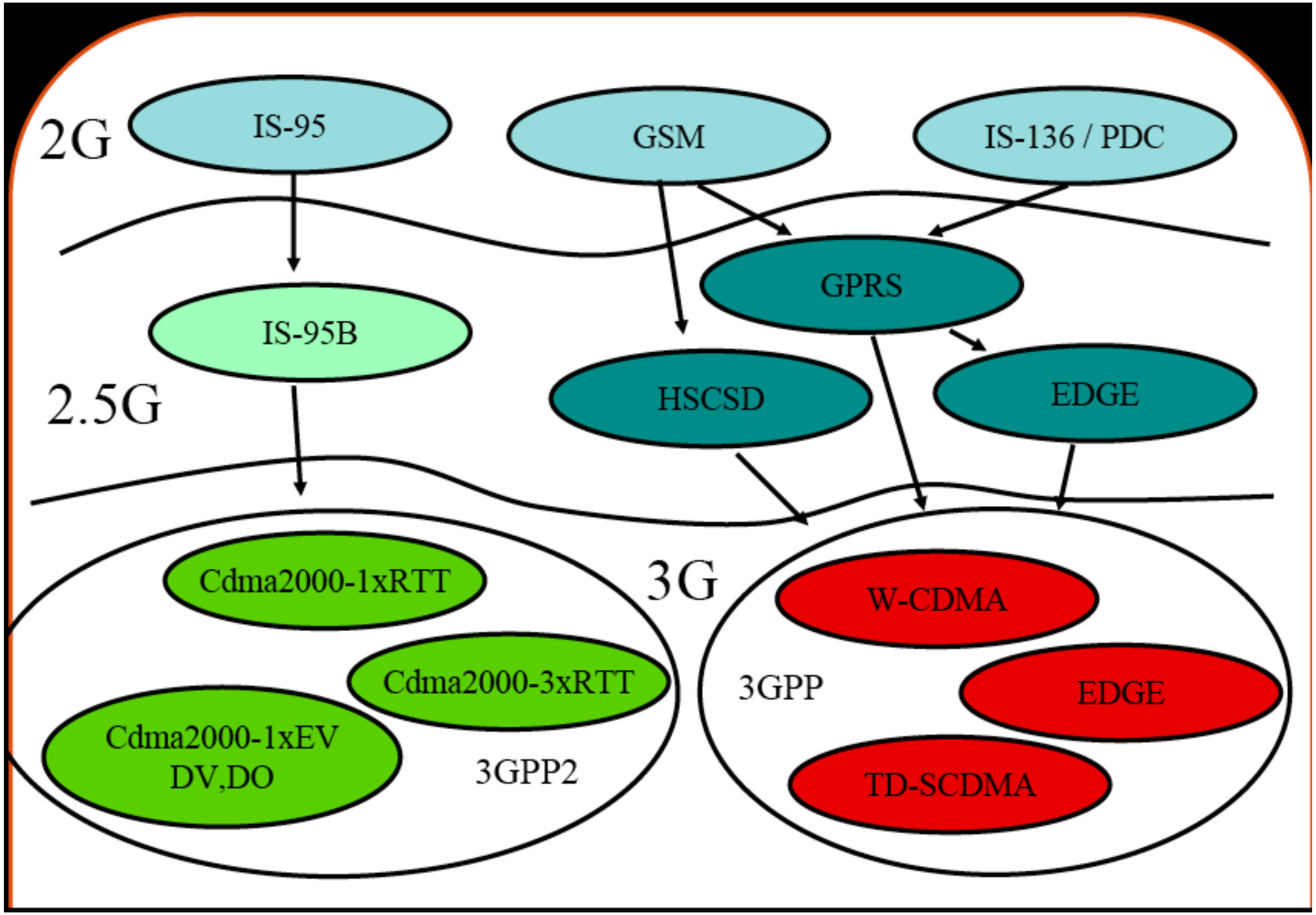


Newer Alternatives

- Code Division Multiple Access (CDMA)
  - Cocktail party analogy: each user uses a unique code, receiver that knows that code can extract out the desired user
  - Recipient of much Qualcomm-fueled hype in the 1990s (Gilder and other analysts bought it all)
  - Contrary to popular belief, *in theory*, CDMA does not allow more users to exist in a fixed bandwidth
  - But, it does allow for some very nice tradeoffs that ultimately increase system capacity
- **All 3G cellular systems use CDMA for multiple access**
- For more information:
  - http://www.ece.utexas.edu/~jandrews/CDMA.html

CDMA …


frequency
time
FDMA
frequency
time
TDMA
frequency
time
CDMA


2G
IS-95
GSM
IS-136 / PDC
GPRS
IS-95B
2.5G
HSCSD
EDGE
Cdma2000-1xRTT
3G
W-CDMA
Cdma2000-3xRTT
3GPP
EDGE
Cdma2000-1xEV
DV,DO
3GPP2
TD-SCDMA

CDMA

Se $c_1(t)$ è ortogonale a $c_i(t)$, $\forall i \neq 1$

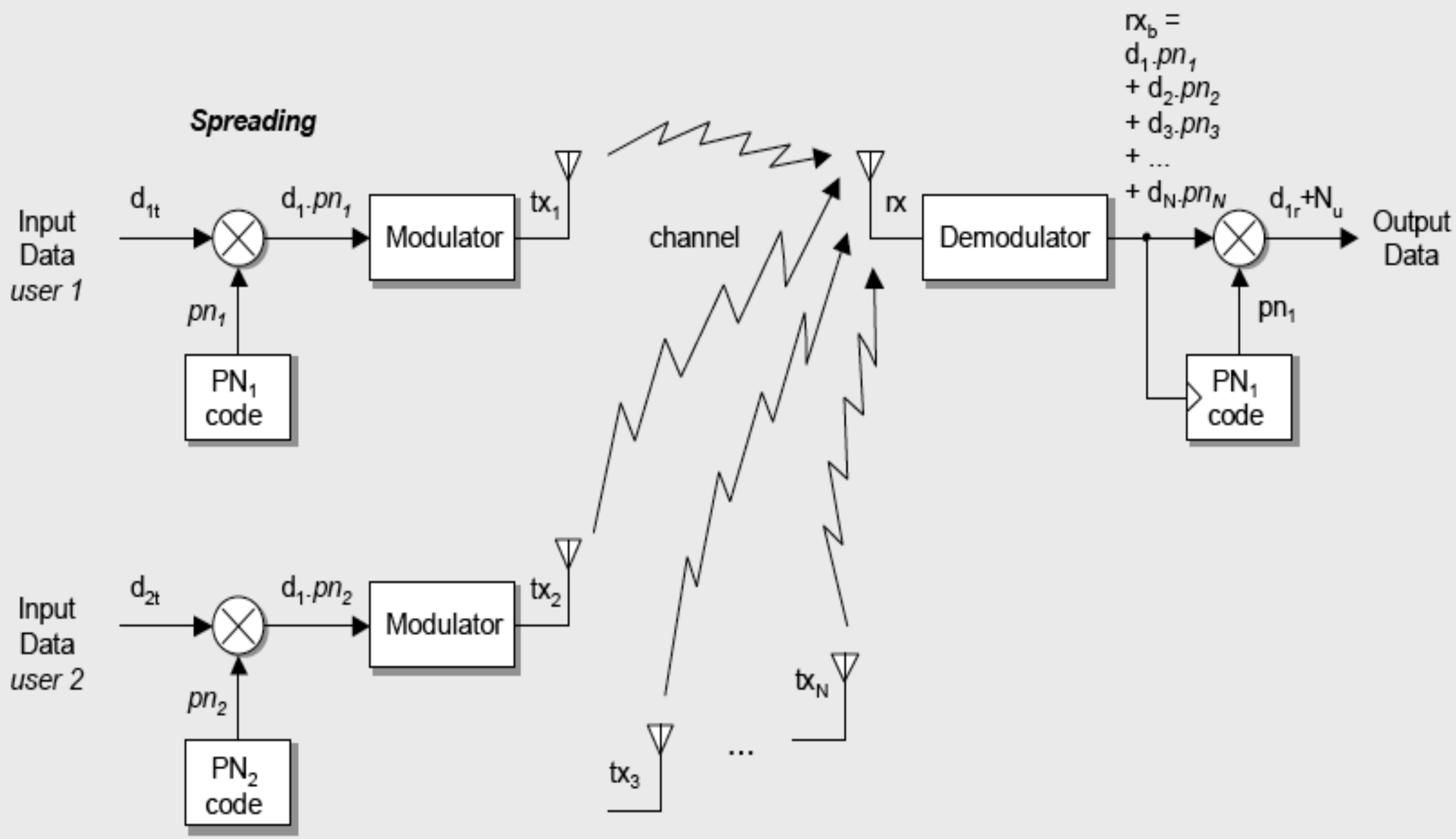
$$\rightarrow \int s(t) \cdot c_1(t)\, dt = \int b_1(t) \cdot c_1^2(t)\, dt + 0 + 0 + \dots$$

$$+ \int b_1(t) \underbrace{c_1(t)\, c_i(t)}_{\rightarrow\, 0\ !!!} dt$$

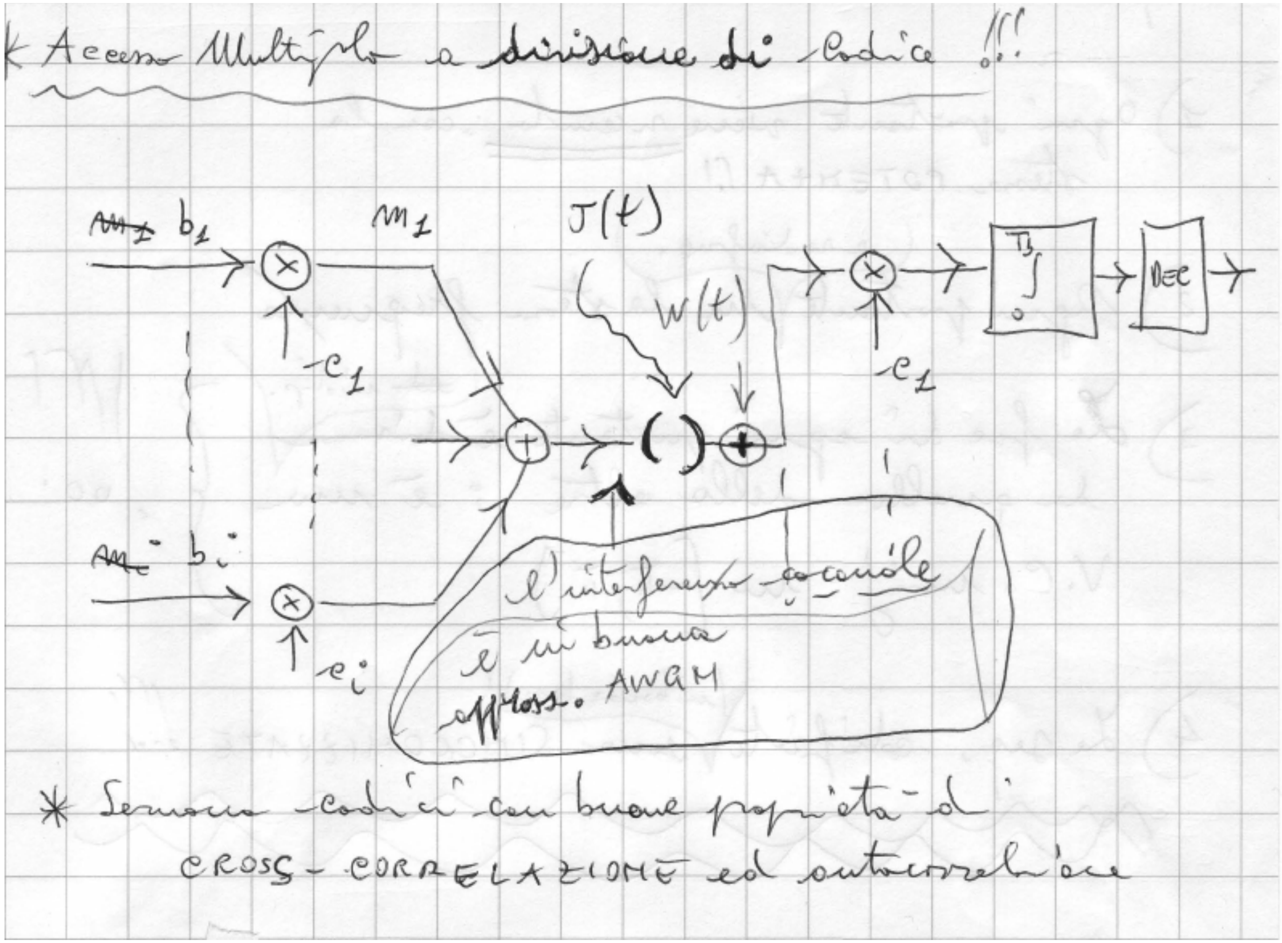
$\rightarrow$ Sopravvive solo il termine che deve essere demodulato ...

In CDMA each user:

- has it's own PN code
- uses the same RF bandwidth
- transmits simultaneously (asynchronous or synchronous)

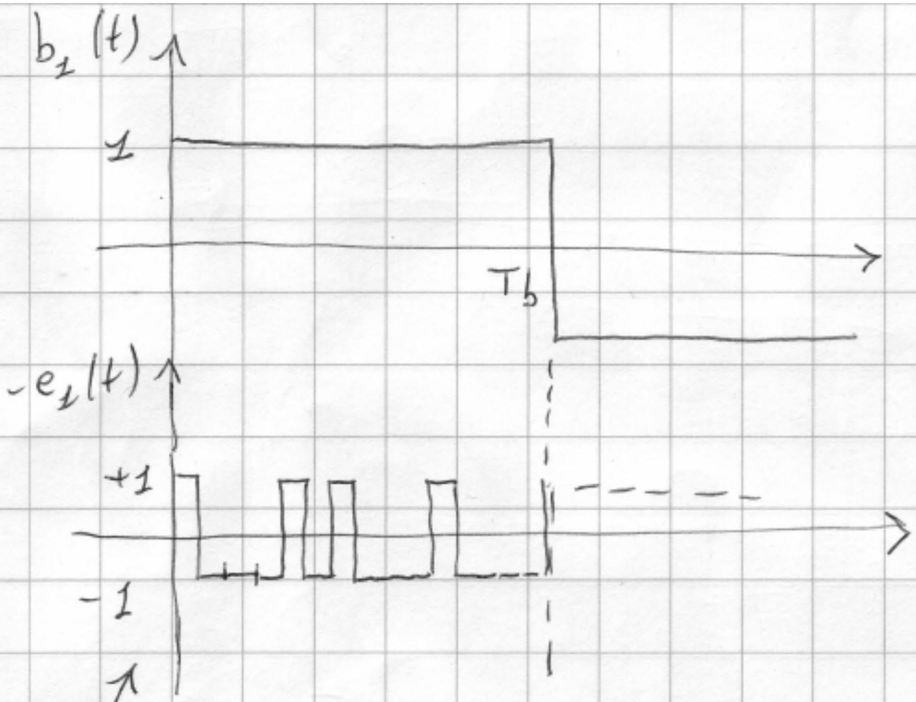


CDMA: basic idea



The used codes should have:

1) Good auto-correlation;
2) Good cross-correlation.



$$m_1(t)\cdot c_1(t) \rightarrow b_1 \cdot c_1 \cdot c_1 = b_1$$

$$m_1 \cdot c_2 = b_1 c_1 c_2$$

tende ad avere effetto = 0!!

$$\int_0^{T_b} c_1^2(t)\,dt = 1 \cdot T_b \quad , \quad \int_0^{T_b} c_1(t)\cdot c_2(t)\,dt = 0$$

$$\int_0^{T_b} b_1(t)\cdot c_1^2(t)\,dt = \int_0^{T_b} b_1(t)\cdot 1\,dt = 1 \cdot T_b$$

Se b_1 è negativo $\longrightarrow -1 \cdot T_b$

Codes for CDMA

* AUTO-CORRELAZIONE → deve essere quanto più impulsiva
↳ buono spreading in freq.
↳ contrasta il fenomeno dei cammini multipli.
↳ facilita la SINCRONIZZAZIONE (RAKE Receiver ---)

* CROSS-CORRELAZIONE → riduce le interferenze tra i vari messaggi

Auto-correlation:

better if it is white-noise like (good spreading performance, good with multipath fading, easier synchronization);

Cross-correlation:

if low, it reduces the inter-message interference.

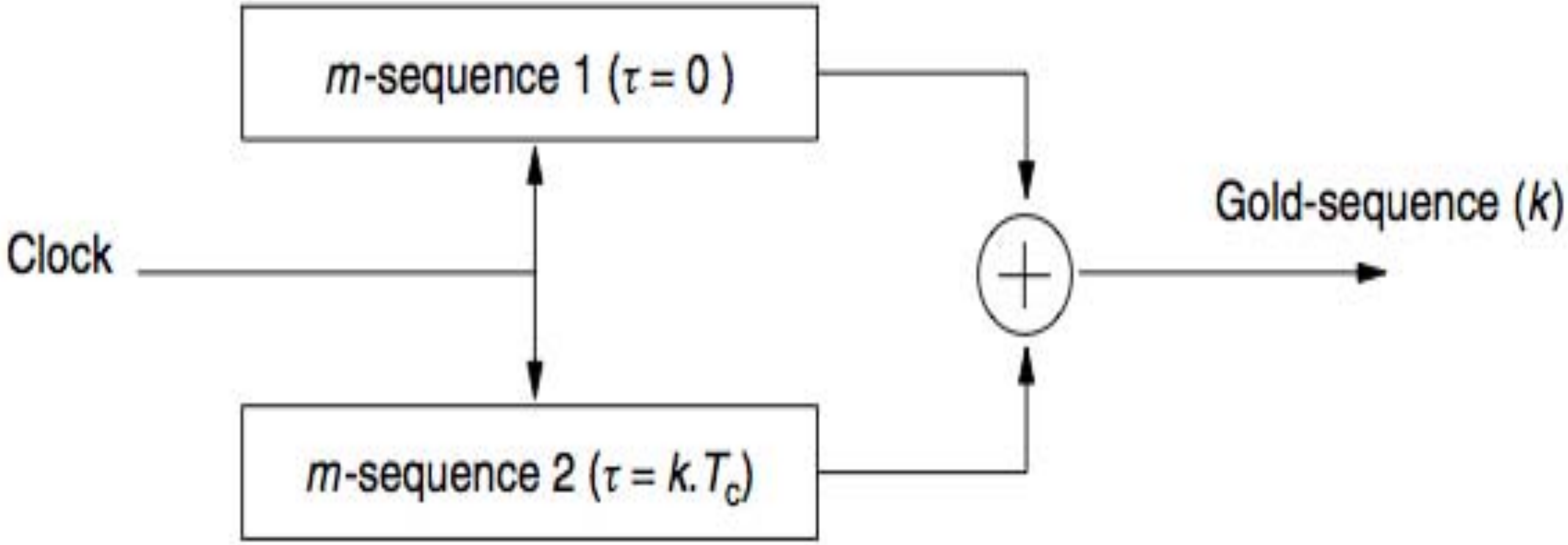


Figure 5.21 General structure of a gold codes generator

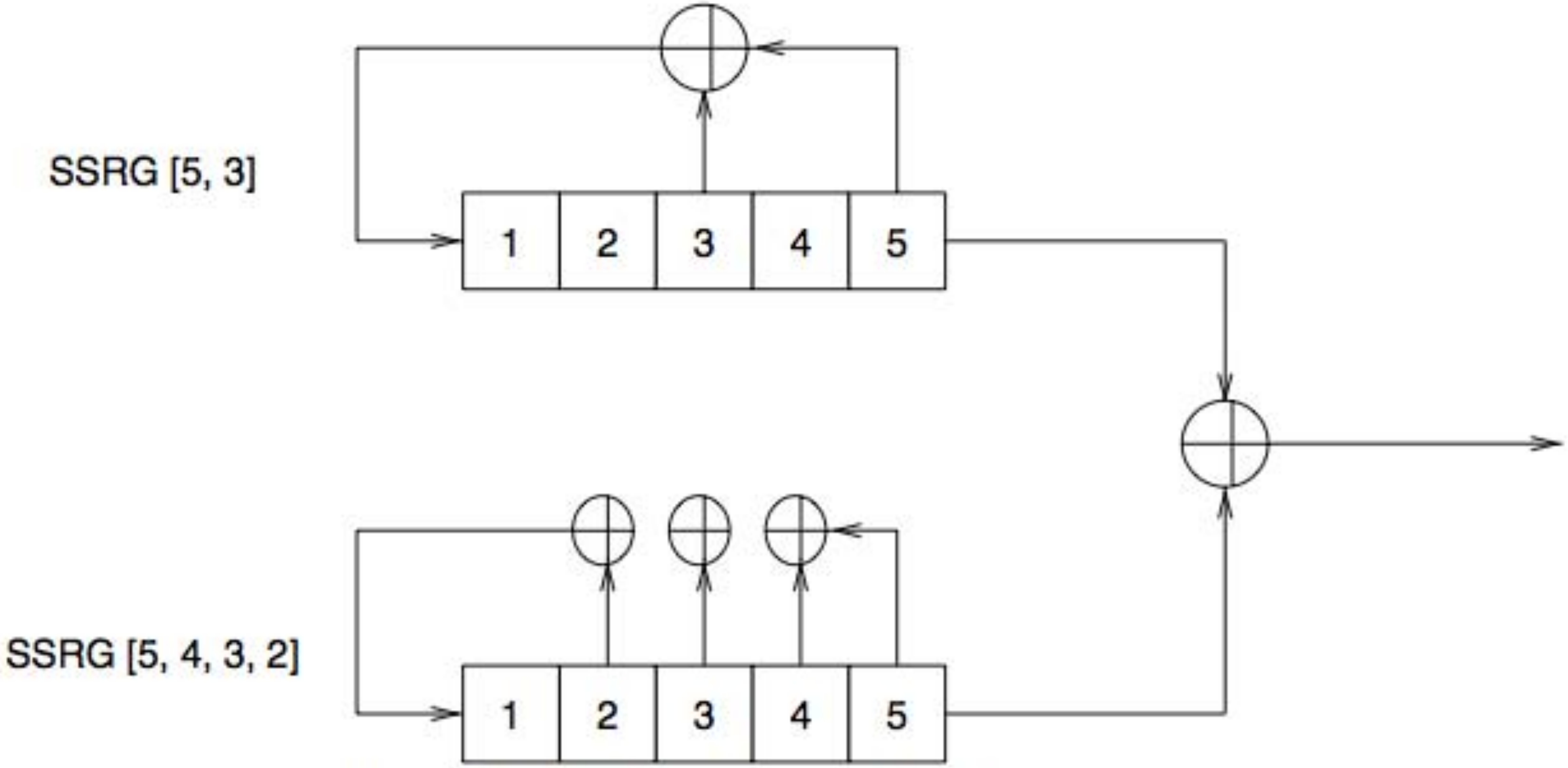
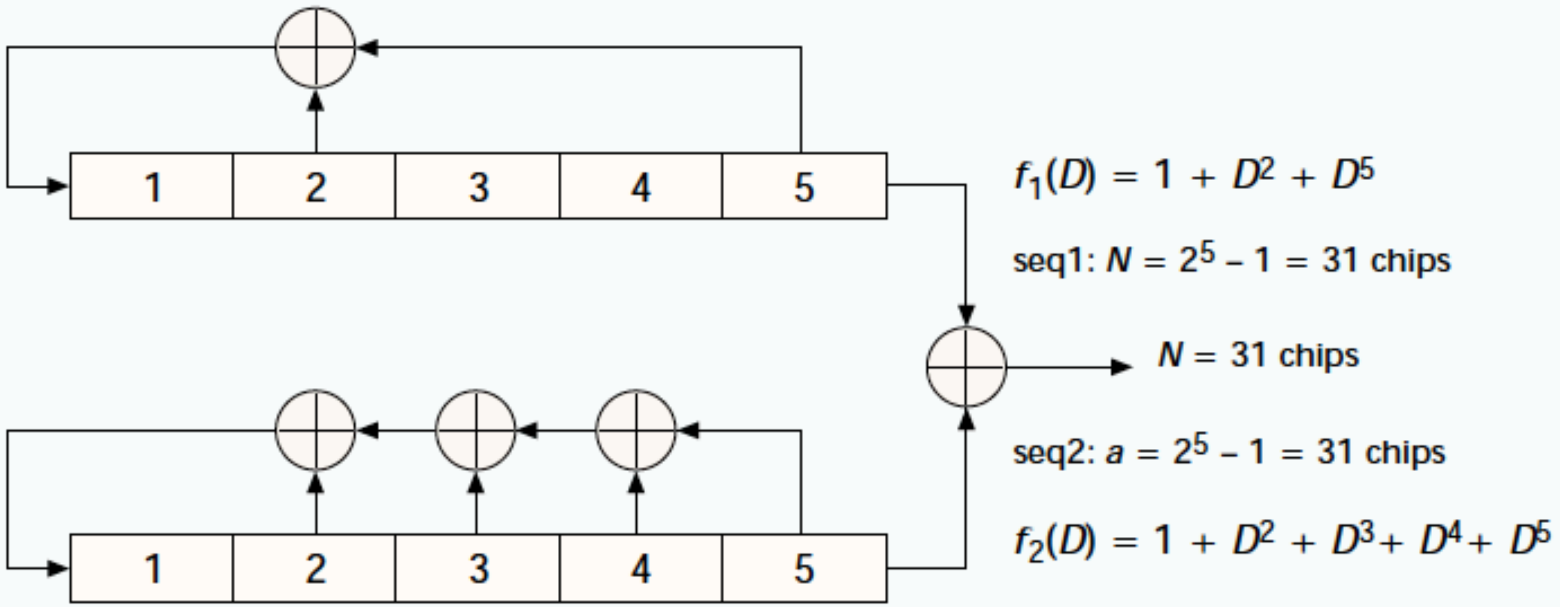


Figure 5.22 Example of gold codes generators



The 25 + 1 = 33 codes generated by this structure:

Sequence 1:	1111100011011101 010000 100101100
Sequence 2:	1111100100110000 101101 010001110
0 shift combination:	0000000111101101 111101 110100010
1 shift* combination:	0000101010111100 001010 000110001
.....	
30 shift combination:	1000010001000101 000110 001101011

*Shift of sequence 2 to the left

Figure 6. *An illustration of generating a Gold code set.*

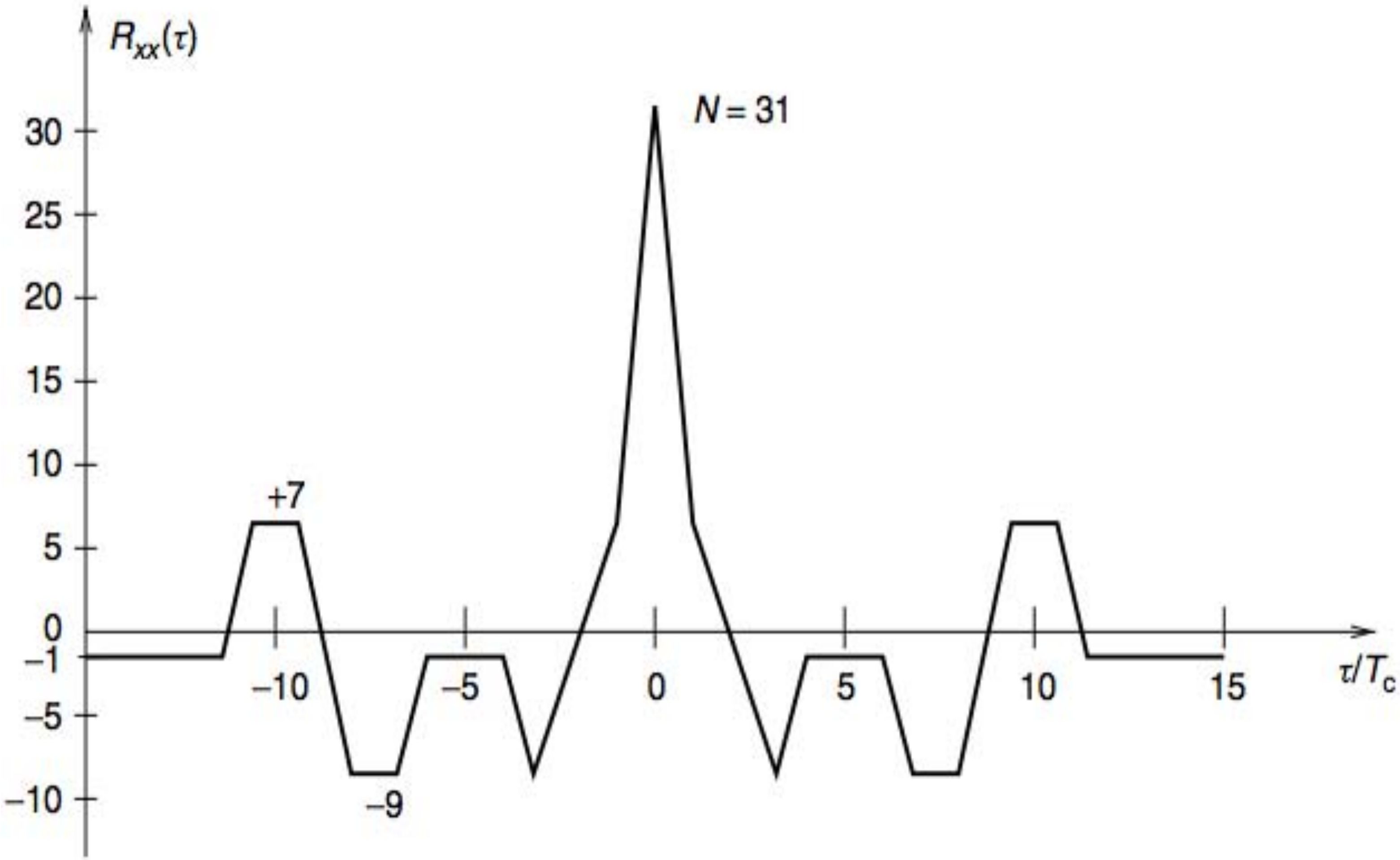
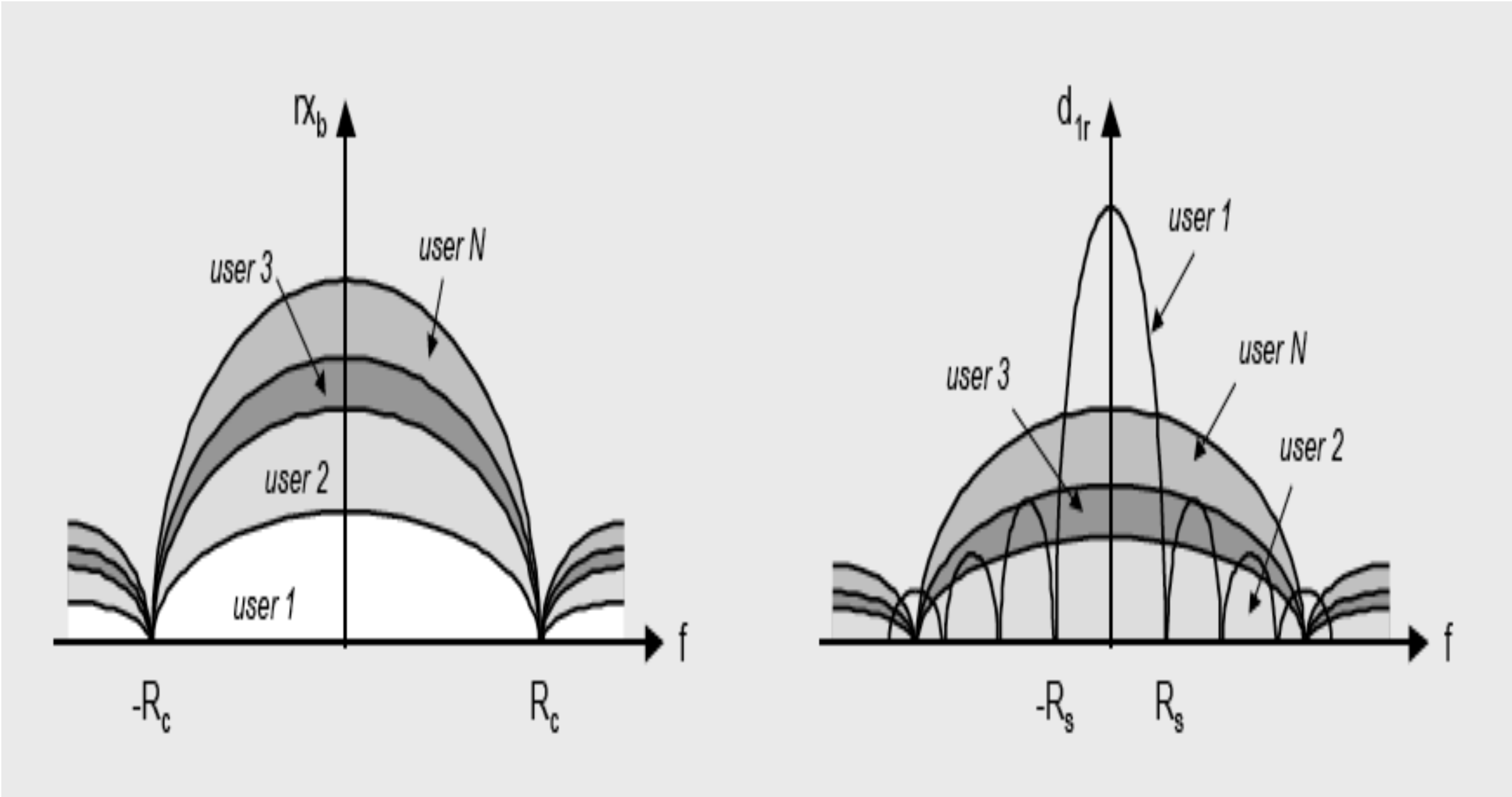
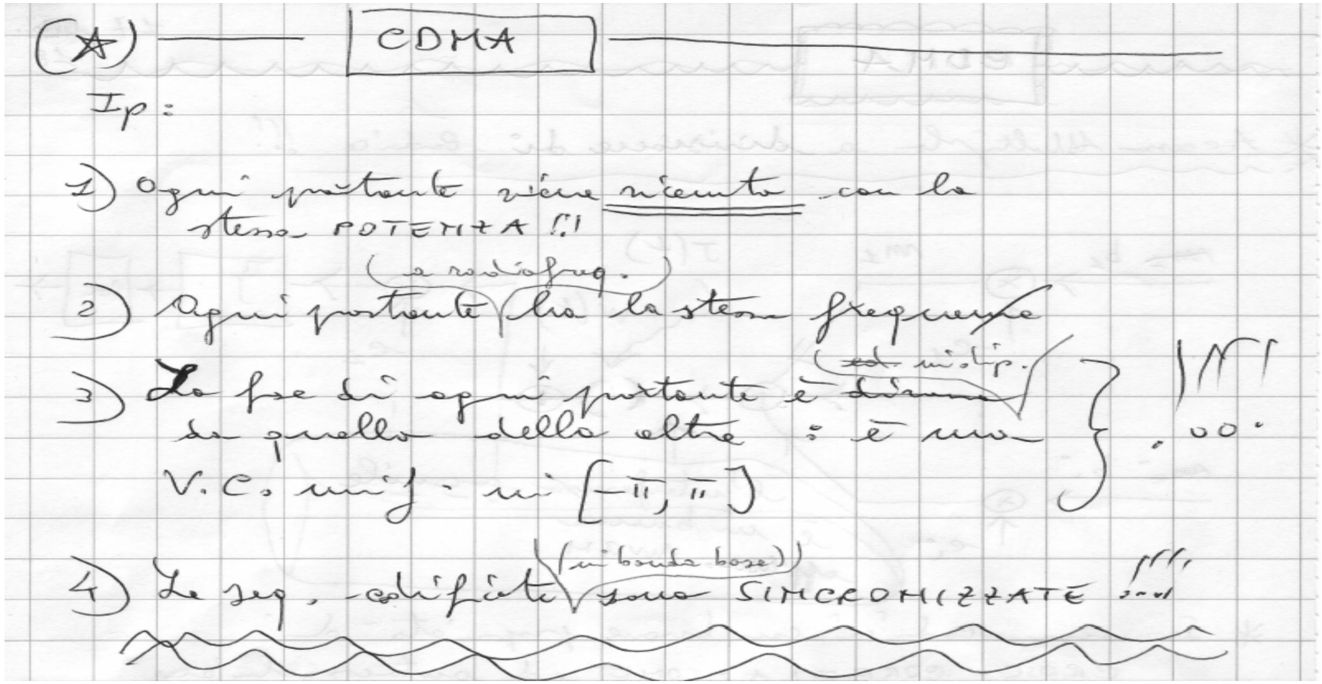


Figure 5.23 Crosscorrelation of gold codes sequences

Interferences in CDMA



Performance of CDMA


(★) CDMA

Ip:

1) ogni portante viene ricevuta con la stessa POTENZA !!

2) ogni portante (a radiofreq.) ha la stessa frequenza

3) La fase di ogni portante è (stat. indip.) ~~diversa~~ da quella delle altre: è una v.c. unif. in $[-\pi, \pi]$!!! ...

4) Le seq. codificate (in banda base) sono SINCRONIZZATE !!!

1) Every carrier is “received” with the same power level;
2) Every radio-frequency carrier has the same central frequency;
3) The phase of the different radio-frequency carriers are independent random variables, uniform in [-pi, +pi];
4) The decoded (base-band) sequences are perfectly synchronized.

P(E) of CDMA

($\star$)

Se $M_T =$ → n° di ~~seq. a max. lunghe~~ codici utilizzati

↳ Se ip. che ~~siano~~ codici ORTOGONALI (~~non è vero al 100%~~)

↳ CDMA con M_T utenti che ~~arrivano~~ ricevono con la stessa potenza (mi dip. tra loro)

$$* \quad P_b(E) \simeq Q\left(\sqrt{\frac{E_b}{\frac{N_0}{2} + \frac{(M_T-1)}{G} E_b}}\right)$$

è (circa) come un rumore AWGN (prima approx.)

è il contributo degli (M_T-1) interferenti

Prestazioni del CDMA

$$* \quad P_b(E) \simeq Q\left(\sqrt{\frac{E_b}{\frac{N_0}{2} + \frac{(M_T-1)}{G}E_b}}\right)$$

è (circa) come un rumore AWGN (primissima approx.)

è il contributo degli (M_T-1) interferenti

È il contributo dovuto al rumore

OCCHIO!!! ...

le M_T portanti hanno fase indipendente!!!! e stessa freq.!!

Si ipotizza che ~~[illegible]~~ incorrelati (contributi)

E_b

$$* \quad P_b(E) \approx Q\left(\sqrt{\frac{G}{M_T - 1}}\right) \qquad \left(\frac{E_b}{G} \cdot (M_T - 1) \;!!!\right)$$

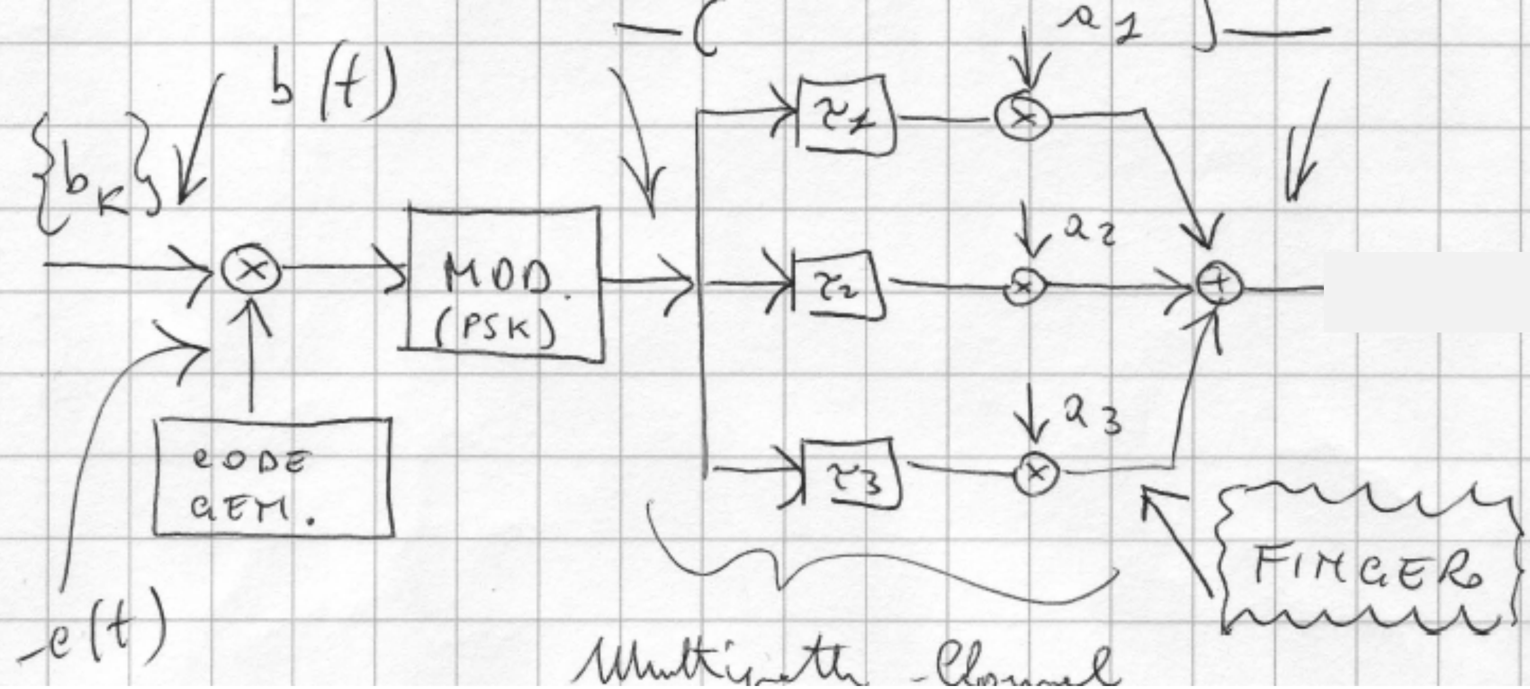
dipende solo dal guadagno di processo (G) e dal numero di utenti - - - - (in prima approx.)

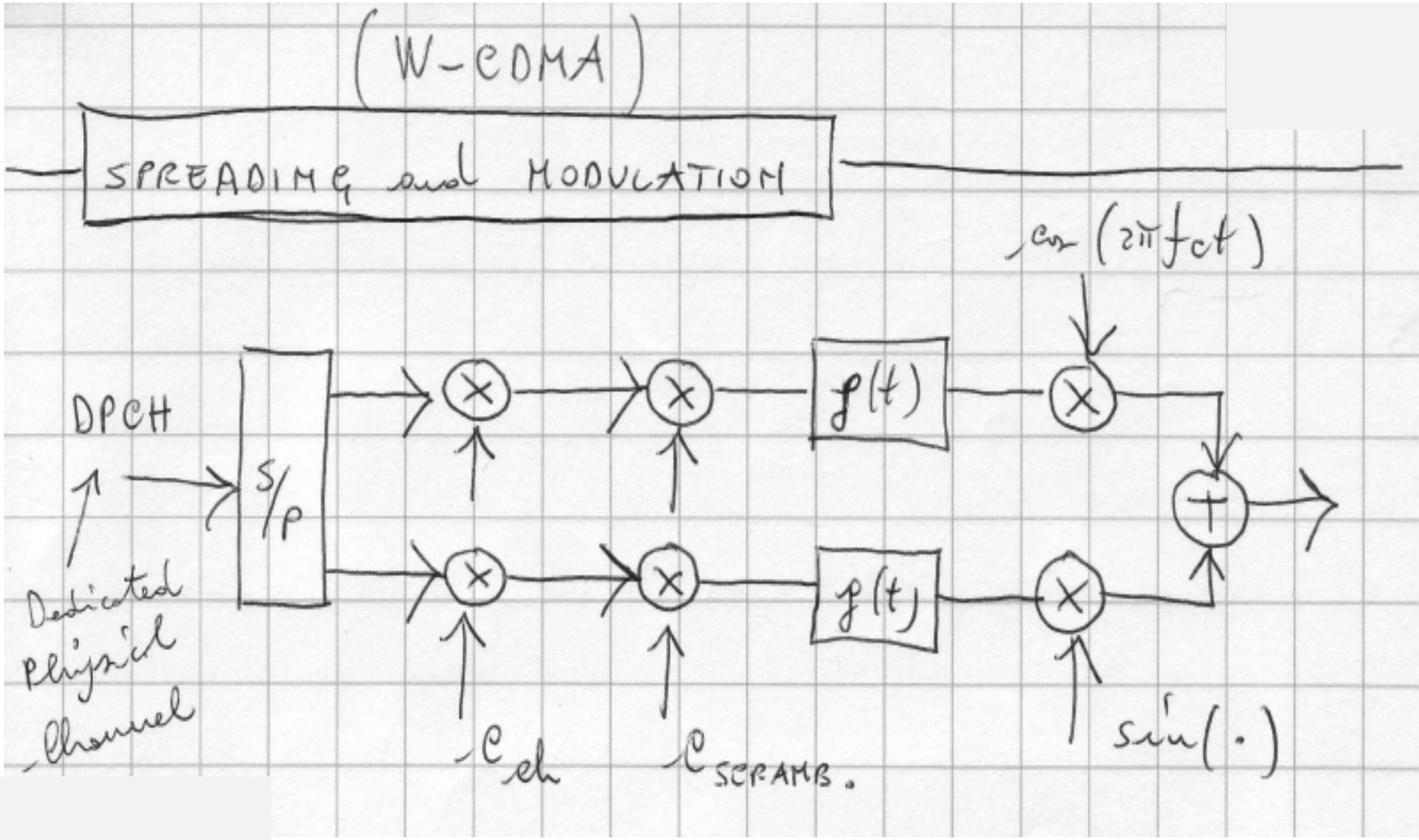
$$* \quad B_T \approx G \cdot \frac{1}{T_b}$$

RAKE receiver

* RAKE receiver → multipath diversity

→ Se il ritardo è maggiore di Tc, l'eco è risolvibile




(W-CDMA)
SPREADING and MODULATION
DPCH
Dedicated physical channel
S/P
c_{ch}
$c_{SCRAMB.}$
$g(t)$
$g(t)$
$\cos(2\pi f_c t)$
$\sin(\cdot)$
+

$$\begin{cases} c_{CH} = \text{codice di CANALIZZAZIONE (O.S.V.F.)} \\ \quad\quad \text{(intra-cella)} \\ c_{SCRAMB.} = \text{codice di SCRAMBLING (10 ms)} \\ \quad\quad \text{(inter-cella)} \\ g(t) = \text{impulso a } \underbrace{\text{coseno}}_{\text{(radice di)}}\text{-rialzato}, \ \delta = 0{,}22. \\ \quad \hookrightarrow \text{(mod. QPSK)} \end{cases}$$

* 512 codici di SCRAMBLING possibili...