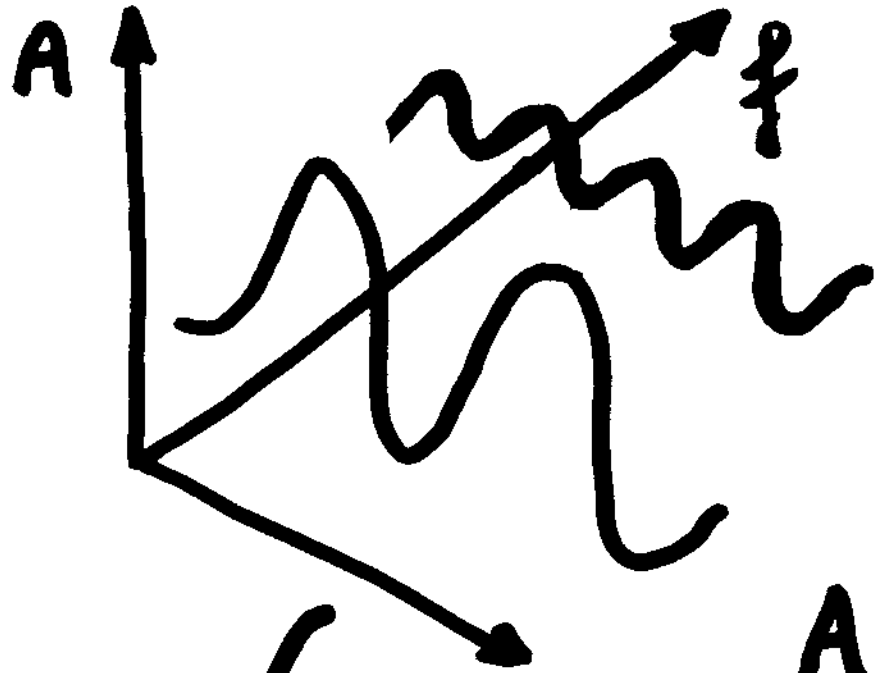
LEZ. 31 e 32

ANALIZZATORI DI SPETTRO

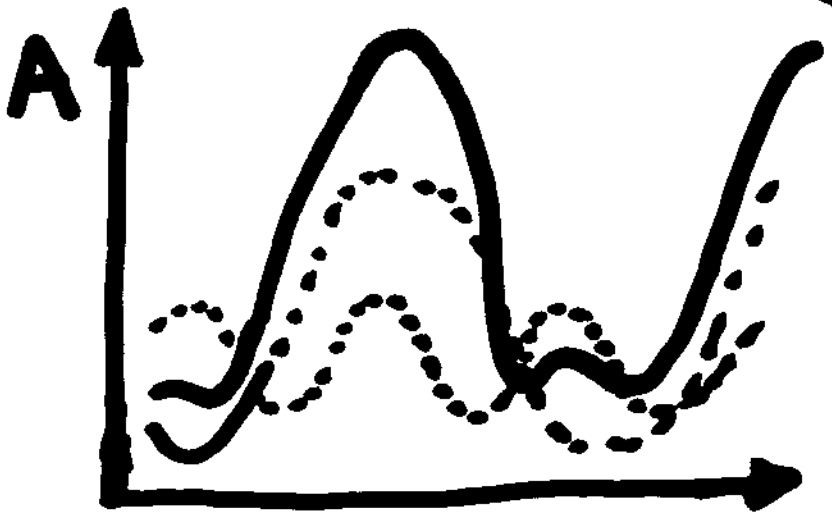
- ANALISI SPETTRALE
- TIPI DI AS E BANDE D'IMPIEGO
- PARAMETRI CARATTERISTICI E LIMITAZIONI DI UNA MISURA CON AS
- AS A BANCO DI FILTRI
- AS A SINGOLO FILTRO ACCORDATO (E AS A ETERODINA)

- AS PER DIFFRAZIONE ALLA BRAGG
- AS OTTICI
- AS A FFT (DIGITALI)
- MISURE CON L'AS

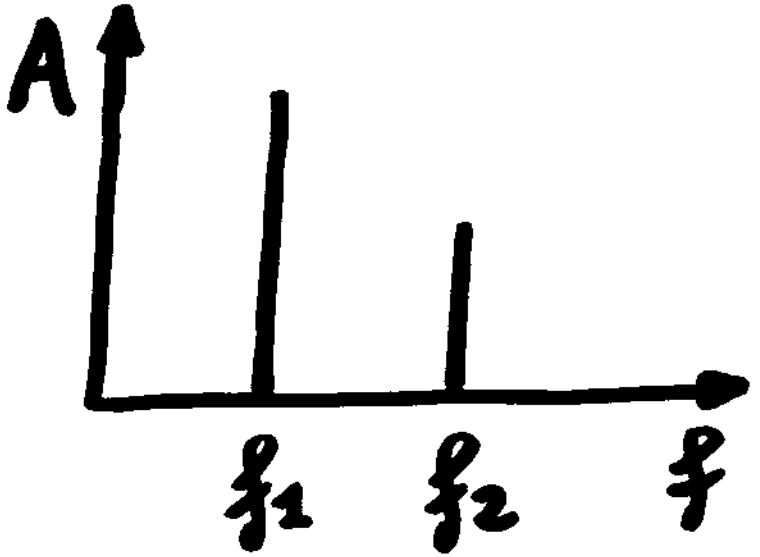
ANALISI SPETTRALE



A. TEMPO/
FREQUENZA



A. NEL TEMPO



A. IN FREQUENZA

ESERCIZIO $v = v_1 + v_2$

$$v_1 = A_1 \sin(2\pi f_1 t + \phi_1)$$

$$v_2 = A_2 \sin(2\pi f_2 t + \phi_2)$$

con $A_1 = 2A_2$ e $f_2 = 2f_1$

RAPPRESENTATE GRAFICAMENTE I DIVERSI SEGNALI (e.g. con MATLAB) NEI DOMINI TEMPO E FREQUENZA (A vs. t e A vs. f)

TRASFORMATA DI FOURIER

$$S(\omega) = \int_{-\infty}^{+\infty} s(t) \exp(-j\omega t)\, dt$$

con $\omega = 2\pi f$

SEGNALE $s(t)$ $\overset{\mathcal{F}}{\Longleftrightarrow}$ SPETTRO $S(f)$

LO SPETTRO DI UN SEGNALE s(t) REALE È

S(f) COMPLESSO (AMPIEZZA E FASE)
REAL E IMAG

NELLA REALTÀ SI POSSONO MISURARE SOLO SPETTRI DI SEGNALI TRONCATI, OSSIA OSSERVATI SU UN TEMPO T FINITO

$$S_T(\omega) = \int_{t_o}^{t_o+T} s(t)\exp(-j\omega t)\,dt$$

GAMME SPETTRALI (SEGNALI)

SUBSONICI	$< 20\,Hz$
AUDIO	$20\,Hz \div 20\,KHz$
HF	$3\,MHz \div 30\,MHz$
RF	$30\,MHz \div 3\,GHz$
M-ONDE	$3\,GHz \div 30\,GHz$
	$30\,GHz \div 300\,GHz$

mm

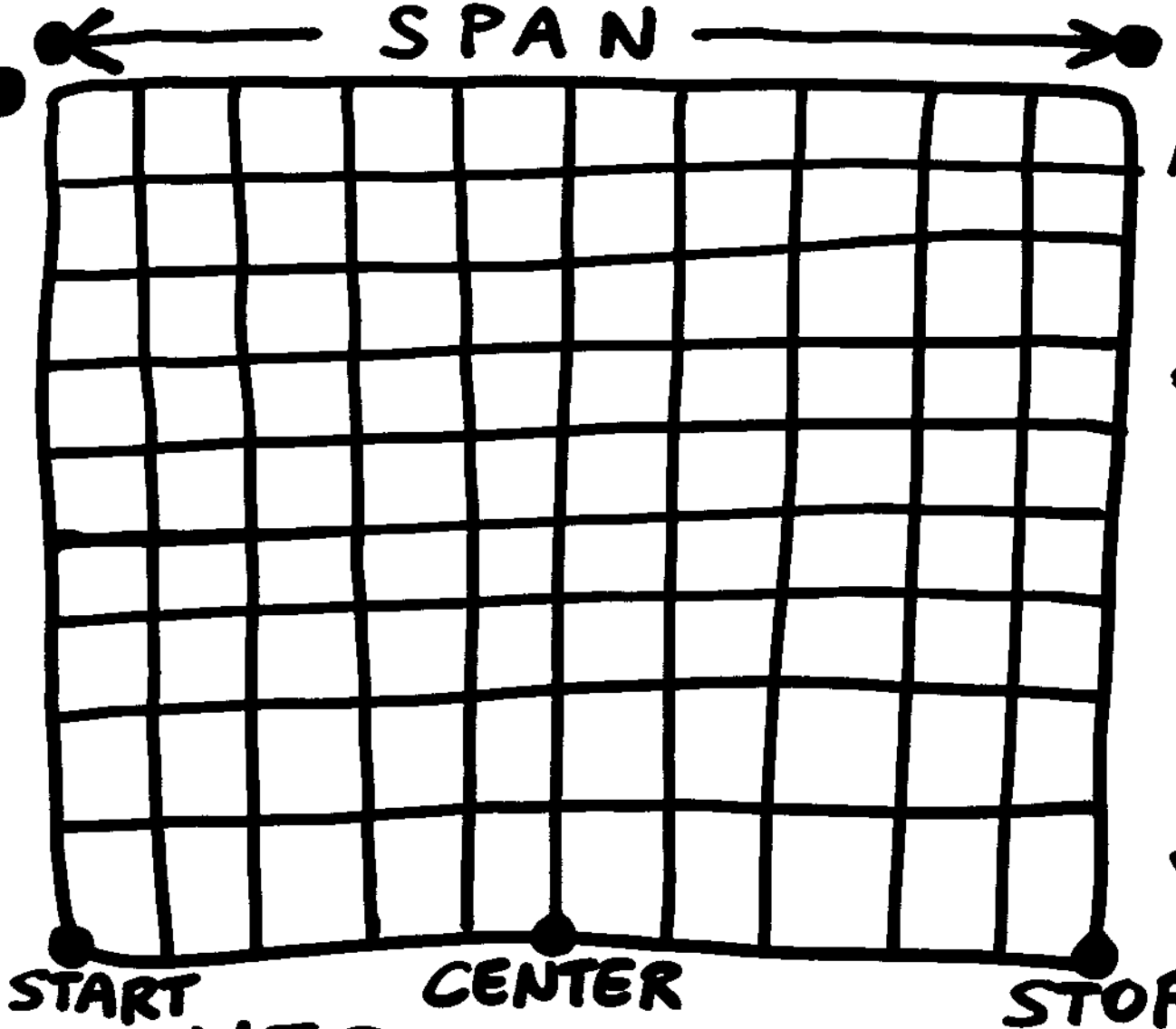
$\lambda = C/f$ LUNGHEZZA D'ONDA

SPETTRO OTTICO E RAGGI X

FIR	1 mm ÷ 30 μm	} IR
MIR	30 μm ÷ 3 μm	} IR
NIR	3 μm ÷ 780 nm	} IR
VIS	780 nm ÷ 380 nm	
UV	380 nm ÷ 180 nm	
VUV	180 nm ÷ 40 nm	
S-X	40 nm ÷ 1 nm	
X	1 nm ÷ 10 pm	

e.g. $\lambda \sim 500$ nm (giallo) $\Longleftrightarrow f \sim 600$ THz

PARAMETRI DI MISURA DI UN AS



RBW
ST
SS

10 DIV. VERT. POTENZA [dBm]
10 DIV. ORIZZ. FREQUENZA [Hz]

REFERENCE LEVEL $RL = [dBm]$

RESOLUTION BANDWIDTH $RBW = [Hz]$

FREQUENCY SPAN $\Delta f_{SPAN} = f_{STOP} - f_{START} = [Hz]$

SWEEP TIME $ST = [s]$

SWEEP SPEED $SS = \frac{\Delta f_{SPAN}}{ST} = \left[\frac{Hz}{s}\right]$

MEASUREMENT TIME $MT = \frac{RBW}{SS} = [s]$

EQUIV. POINTS $N = \frac{\Delta f_{SPAN}}{RBW} = ST/MT$

RUM. TERMICO E FONDO DI RUM.

$p_T = KT$ DENS. SPETTRALE $\left[\frac{W}{Hz}\right]$

$K = 1.38 \times 10^{-23} \frac{W}{Hz\,K}$ COST. DI BOLTZMANN

$P_T = p_T B = KTB$ RUMORE TERM. IN UNA BANDA B

PER $T = 290\,K\ (+17°C) \sim$ T. AMB.

SI HA $p_T \cong 4 \times 10^{-21}\,W/Hz \cong -174\,dBm/Hz$

$$P_T = KT \times RBW$$

$$P_T|_{dBm} = 10 \log_{10} \left(\frac{KT \times RBW}{1\,mW} \right) =$$

$$= 10 \log_{10} \left[\frac{KT \times (1Hz)}{1\,mW} \frac{RBW}{(1Hz)} \right] =$$

$$= -174\ dBm + 10 \log_{10} \left[\frac{RBW}{(1Hz)} \right]$$

ESEMPIO

$T \sim$ TEMP. AMB. $\sim 290\,K$

$RBW_1 = 100\,KHz \quad RBW_2 = 1\,KHz$

CALCOLARE LA "SENSIBILITA'"
(MINIMO SEGNALE RIVELABILE) DELL'AS

$$P_{MIN} \sim P_T = p_T \times RBW = KT \times RBW$$

$$P_{MIN,1} \sim -174\,dB[m/Hz] + 50\,dB[Hz] = -124\,dBm$$

$$P_{MIN,2} \sim -174\,dB[m/Hz] + 30\,dB[Hz] = -144\,dBm$$

$P_{MIN,1} = -130\,dBm + 6\,dB = 4 \times 10^{-16}\,W$

$P_{MIN,2} = -150\,dBm + 6\,dB = 4 \times 10^{-18}\,W$

SE IL SEGNALE DA MISURARE É UNA SINUSOIDE CON AMPIEZZA EFFICACE $V_{s,eff} = 100\,mV$ ED É MISURATO SU $R = 50\,\Omega$, SI AVRA' UNA POTENZA

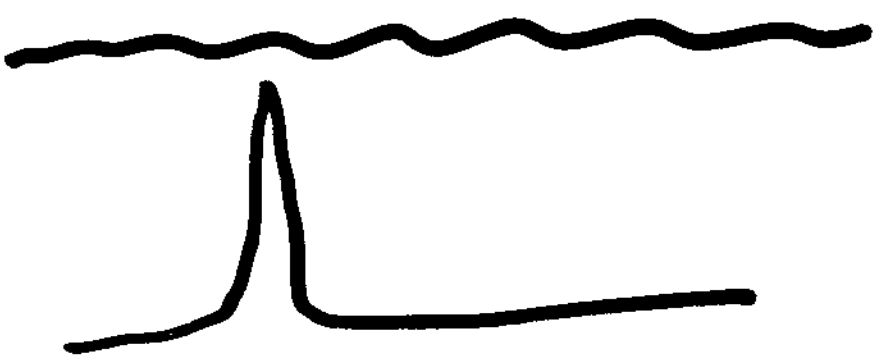
$$P_s = \frac{V_{s,eff}^2}{R} = \frac{V_{s,p}^2}{2R} = 2 \times 10^{-16}\,W$$

NEL PRIMO CASO ($RBW_1 = 100\,KHz$)

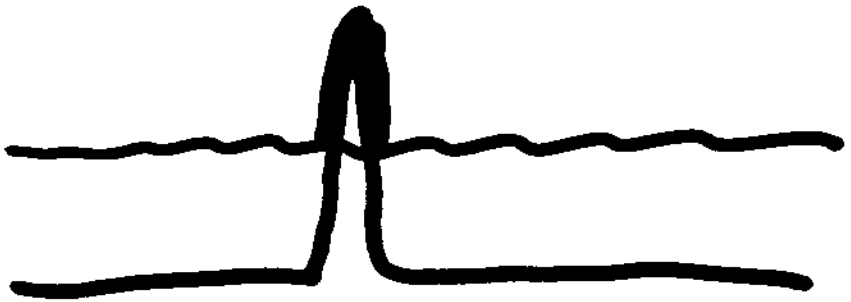
$P_{NOISE} = 400\,aW > P_S = 200\,aW$

NEL SECONDO CASO ($RBW_2 = 1\,KHz$)

$P_{NOISE} = 4\,aW \ll P_S = 200\,aW$

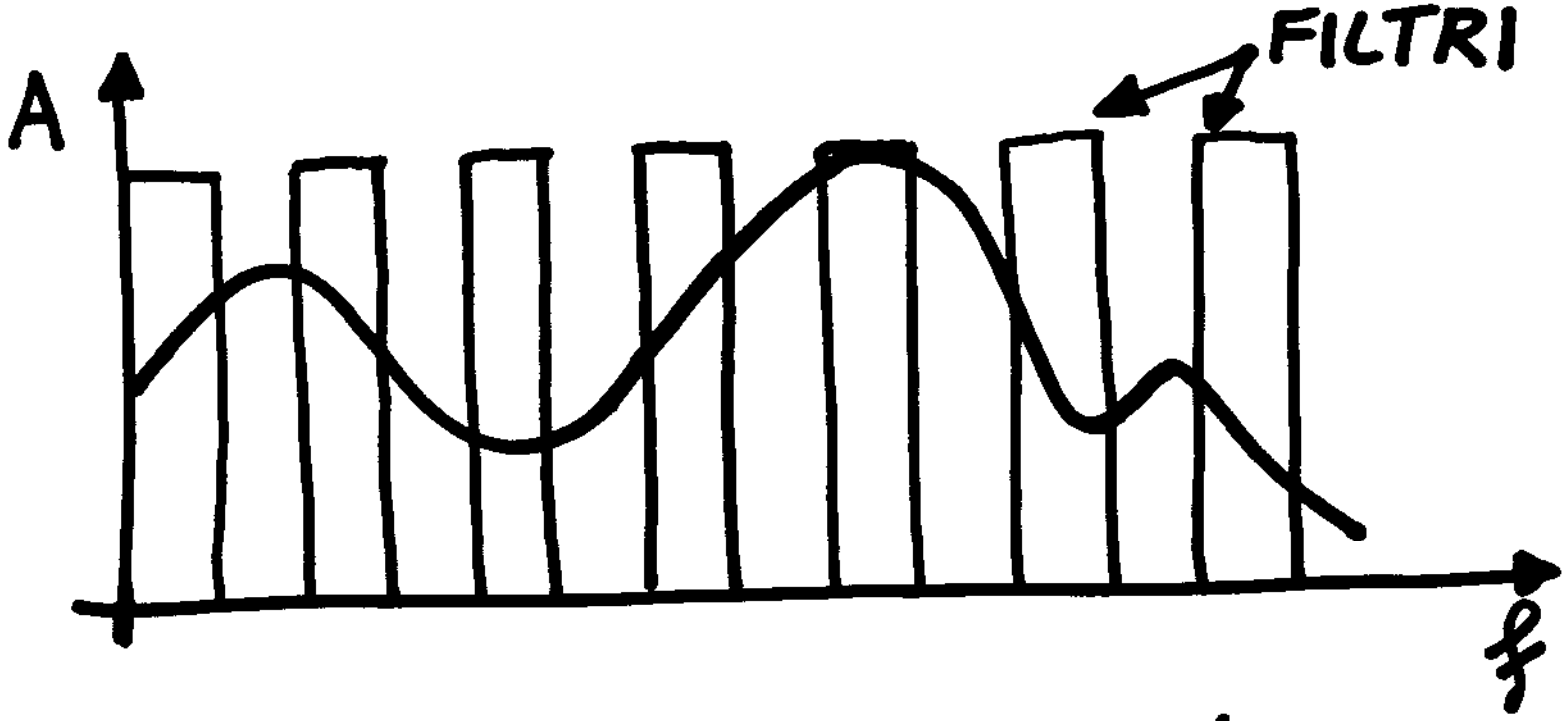


1° CASO



2° CASO

AS A BANCO DI FILTRI

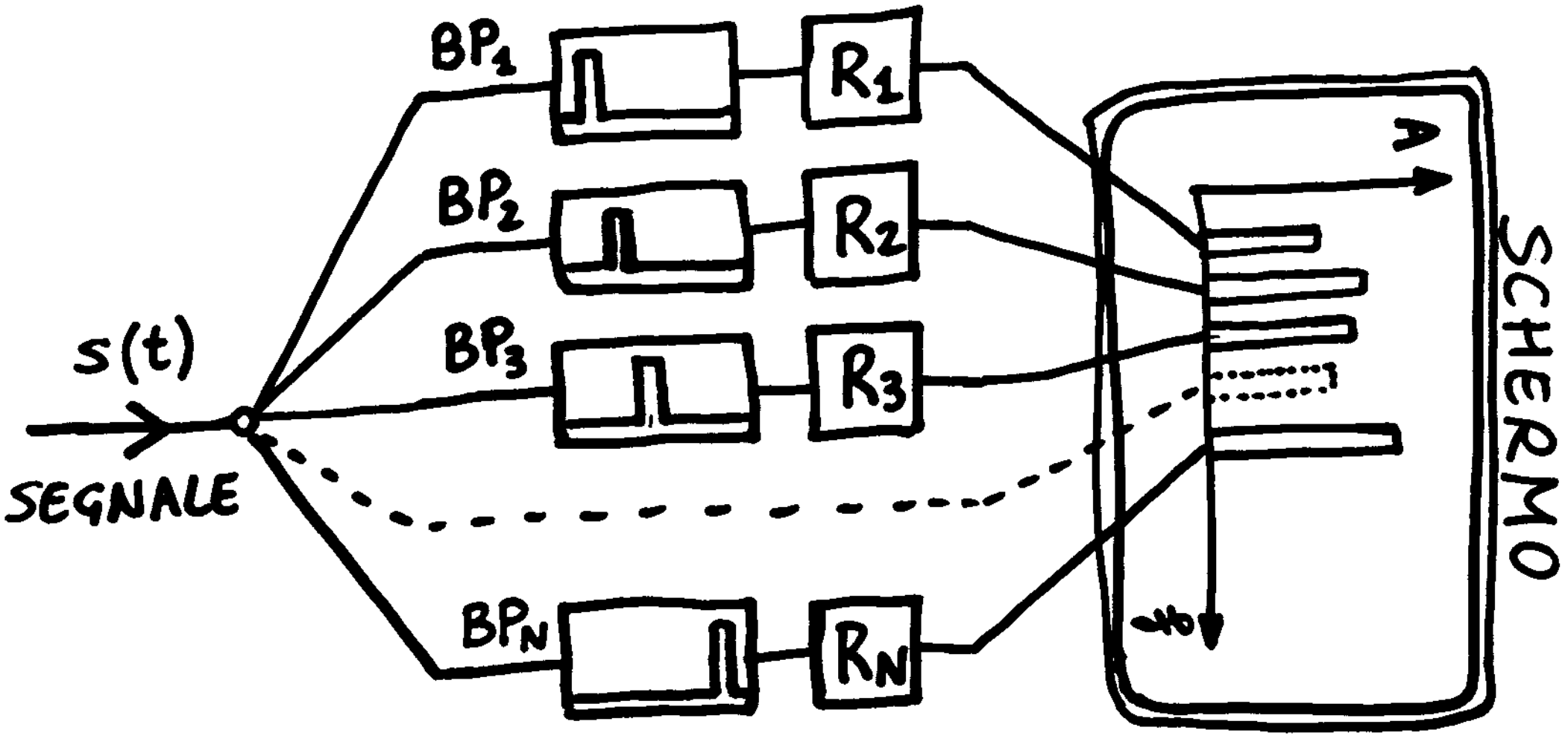


ANALISI PARALLELA ("SIMULTANEA")

IMPIEGO IN BANDA AUDIO

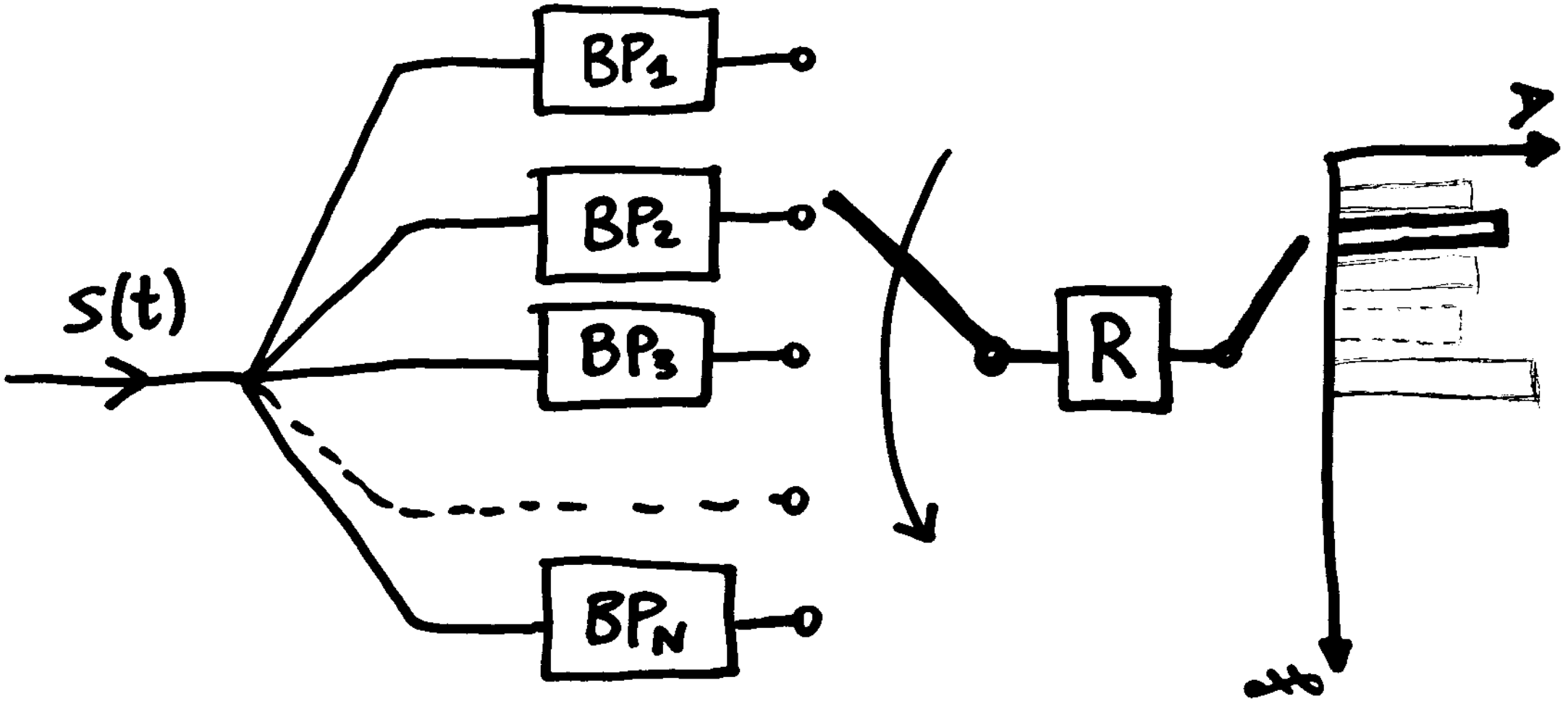
MISURA SEGNALI "NON STAZIONARI"

AS A BANCO DI FILTRI (PIU' R)



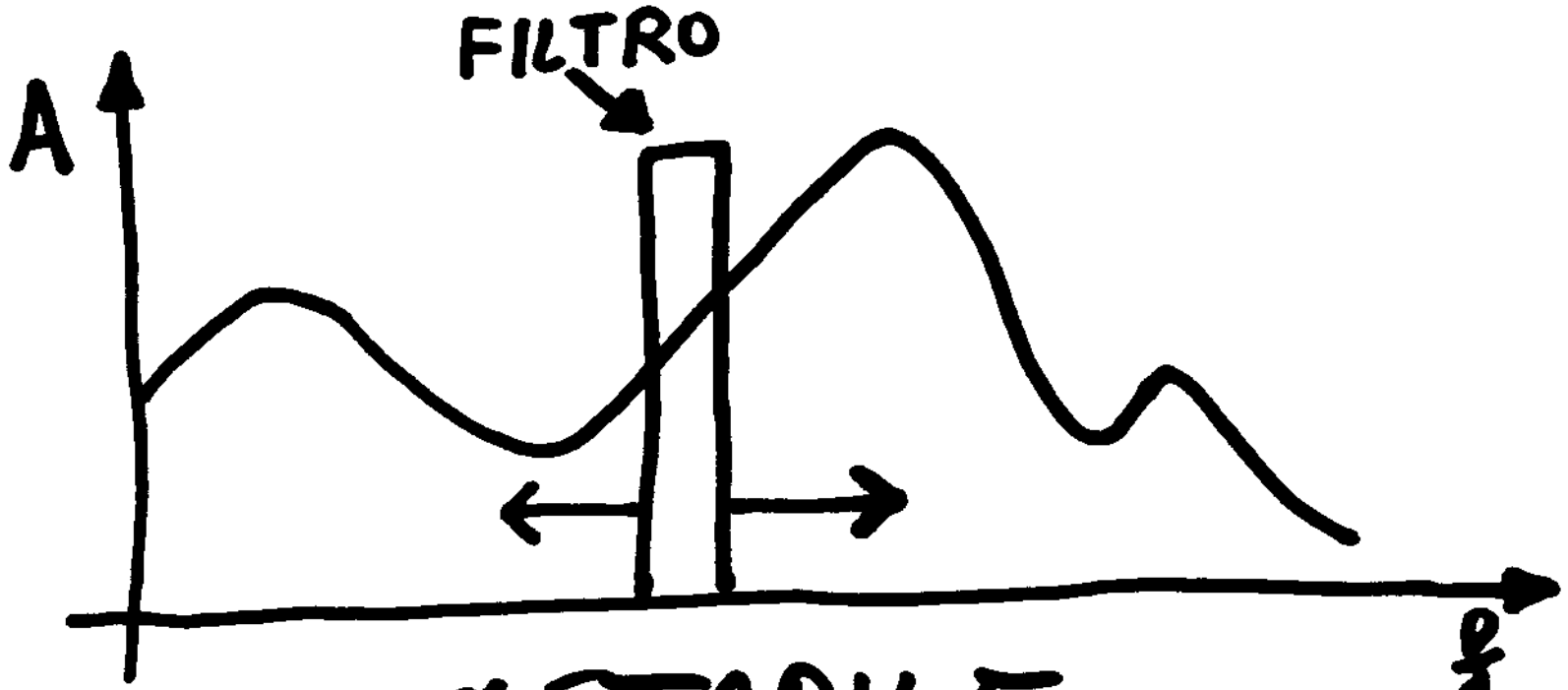
S(f)
SPETTRO

AS A BANCO DI FILTRI (UNR)



ANALISI SEQUENZIALE

AS A FILTRO ACCORDATO

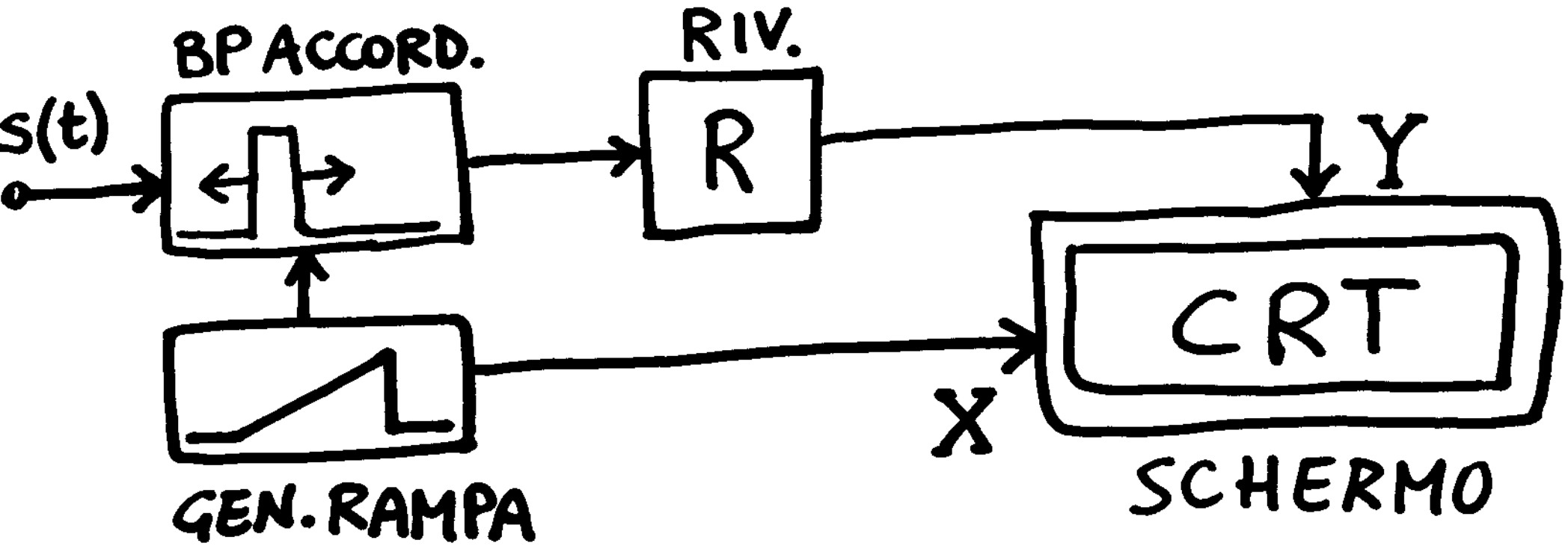


$Q = \frac{\Delta f}{f}$ ≈STABILE CON f

ANALISI SEQUENZIALE

"SI MUOVE IL FILTRO LUNGO LO SPETTRO"

AS A FILTRO ACCORDATO

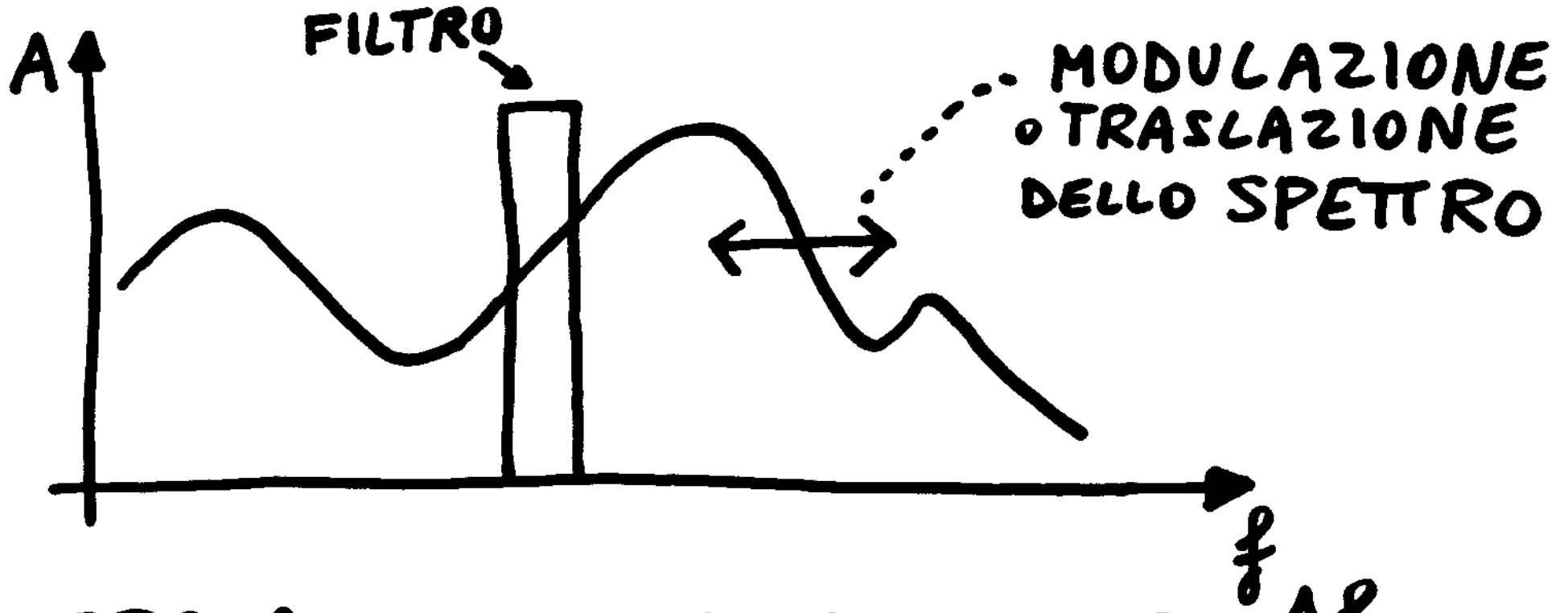


SEMPLICITA' DI COMANDO DEL CRT

MINIMO NUMERO FILTRI E RIVELATORI

Pb. RBW VARIA CON &

AS A ETERODINA

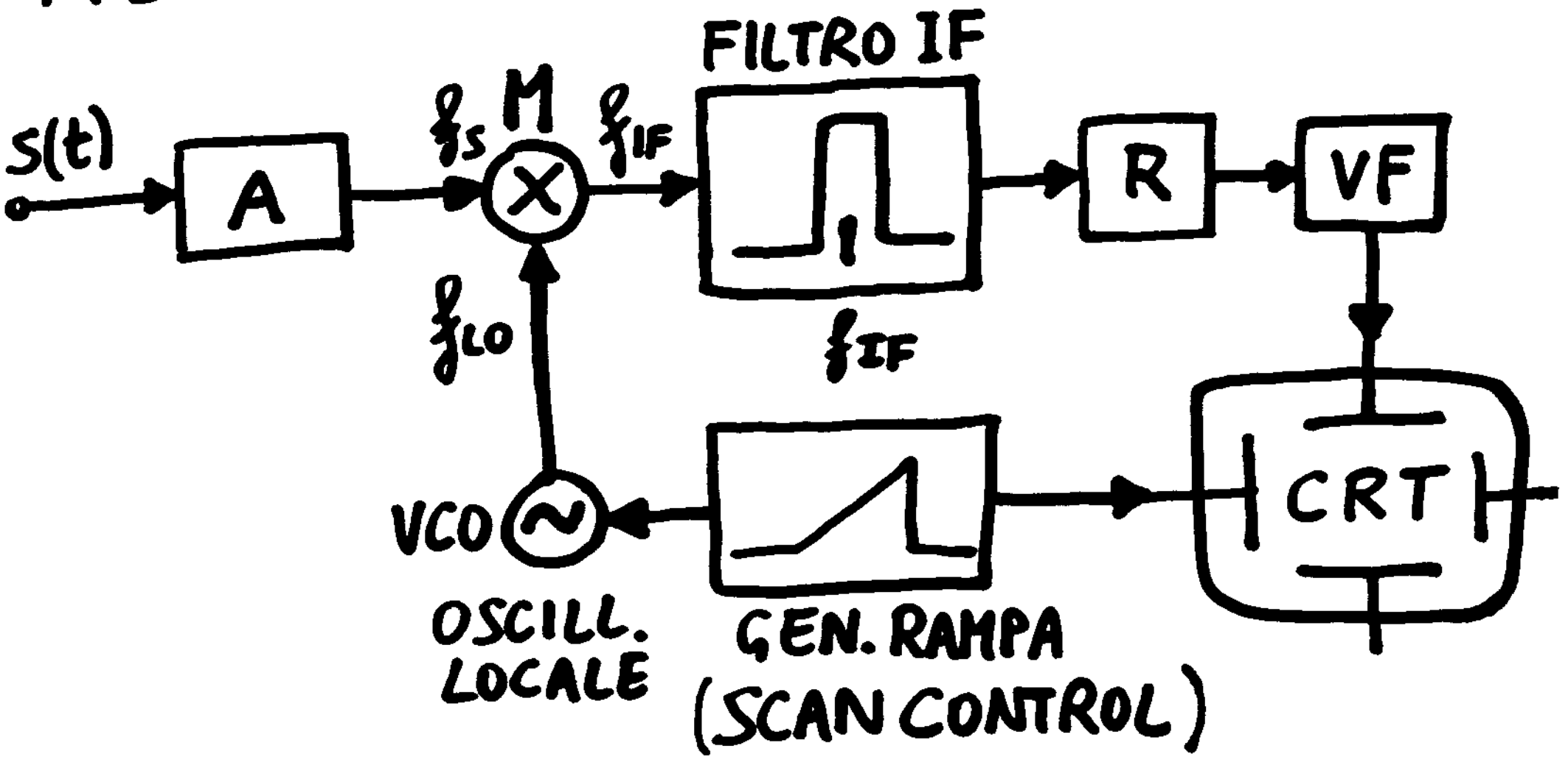


FILTRO A SINTONIA FISSA $Q = \frac{\Delta f}{f} = \text{COST.}$

ANALISI SEQUENZIALE

"SI MUOVE/MODULA LO SPETTRO ATTRAVERSO IL FILTRO"

AS A ETERODINA

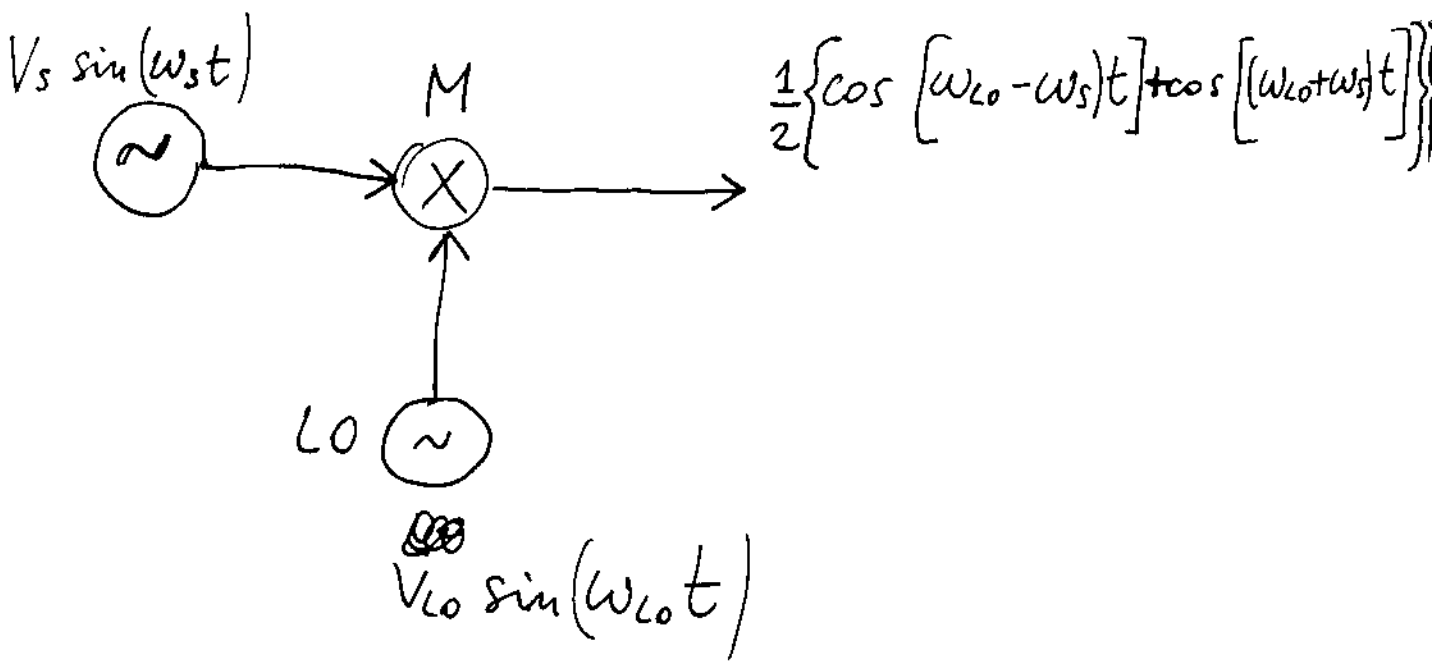


$$f_{IF} = |f_{LO} \pm f_S| \xRightarrow{?} f_{IF} = f_{LO} - f_S$$

$$\sin\alpha \sin\beta = -\frac{1}{4}\left(e^{j\alpha} - e^{-j\alpha}\right)\left(e^{j\beta} - e^{-j\beta}\right) =$$

$$= -\frac{1}{4}\left[e^{j(\alpha+\beta)} - e^{j(\alpha-\beta)} - e^{-j(\alpha-\beta)} + e^{-j(\alpha+\beta)}\right] =$$

$$= \frac{\cos(\alpha-\beta) - \cos(\alpha+\beta)}{2}$$



$$e^{j\theta} = \cos\theta + j\sin\theta$$

$$\cos\alpha = \frac{e^{j\alpha} + e^{-j\alpha}}{2}$$

$$\sin\beta = \frac{e^{j\beta} - e^{-j\beta}}{2j}$$

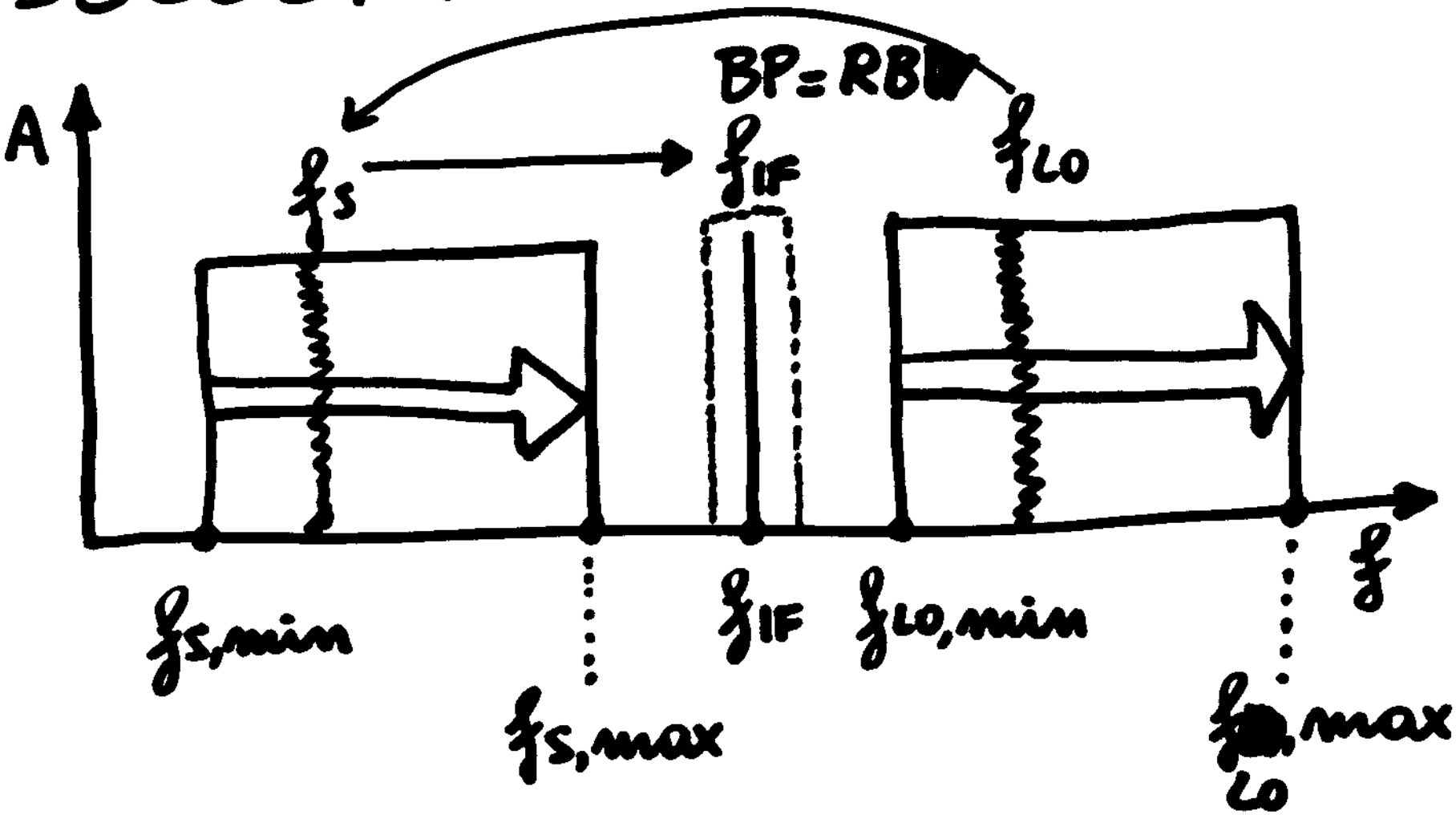
$$\cos\alpha\cos\beta = \frac{1}{4}\left(e^{j\alpha} + e^{-j\alpha}\right)\left(e^{j\beta} + e^{-j\beta}\right) =$$

$$= \frac{1}{4}\left[e^{j(\alpha+\beta)} + e^{j(\alpha-\beta)} + e^{j(-\alpha+\beta)} + e^{j(-\alpha-\beta)}\right]$$

$$= \frac{1}{4}\left[\left(e^{j(\alpha+\beta)} + e^{-j(\alpha+\beta)}\right) + \left(e^{j(\alpha-\beta)} + e^{-j(\alpha-\beta)}\right)\right] =$$

$$= \frac{\cos(\alpha+\beta) + \cos(\alpha-\beta)}{2}$$

SELEZIONE DELLA FREQ. INTERMEDIA



SE $f_{LO} > f_{IF} > f_S$

ALLORA $f_{IF} = f_{LO} - f_S$

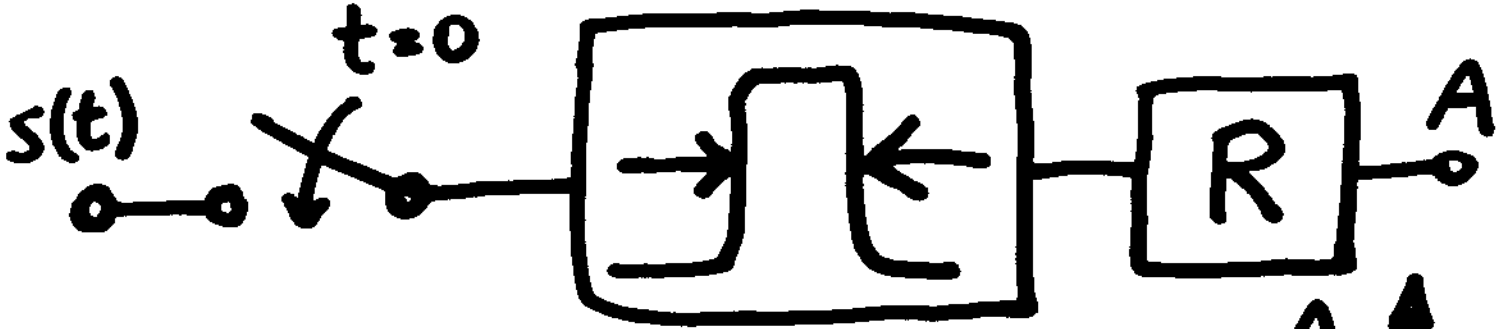
ELIMINO LA FREQUENZA IMMAGINE

FILTRI STRETTI (RBW "PICCOLA") DANNO UNA ELEVATA RISOLUZIONE SPETTRALE MA RICHIEDONO TEMPI LUNGHI DI ANALISI (PB. DI NON STAZIONARIETA' DEL SEGNALE)

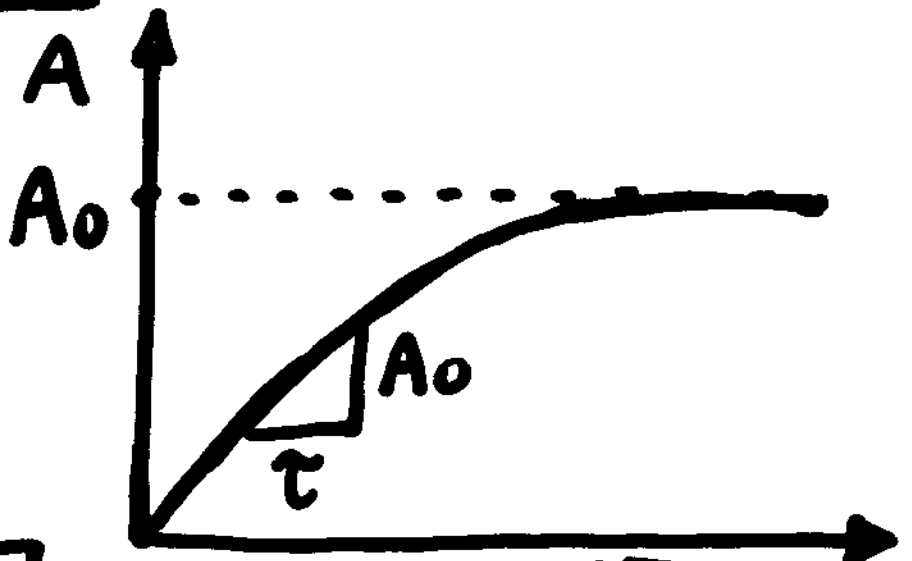
$$\text{BANDA} \propto \frac{1}{\text{TEMPO}}$$

SELETTIVITA' E TEMPO DI ASSESTAMENTO DEL FILTRO

B=RBW RESOLUTION BANDWIDTH



LA RISPOSTA DI FILTRO + RIVELATORE NON E' ISTANTANEA



$$A(t) = A_0\left[1 - \exp(-t/\tau)\right] \quad \text{E} \quad \tau \propto \frac{1}{RBW}$$

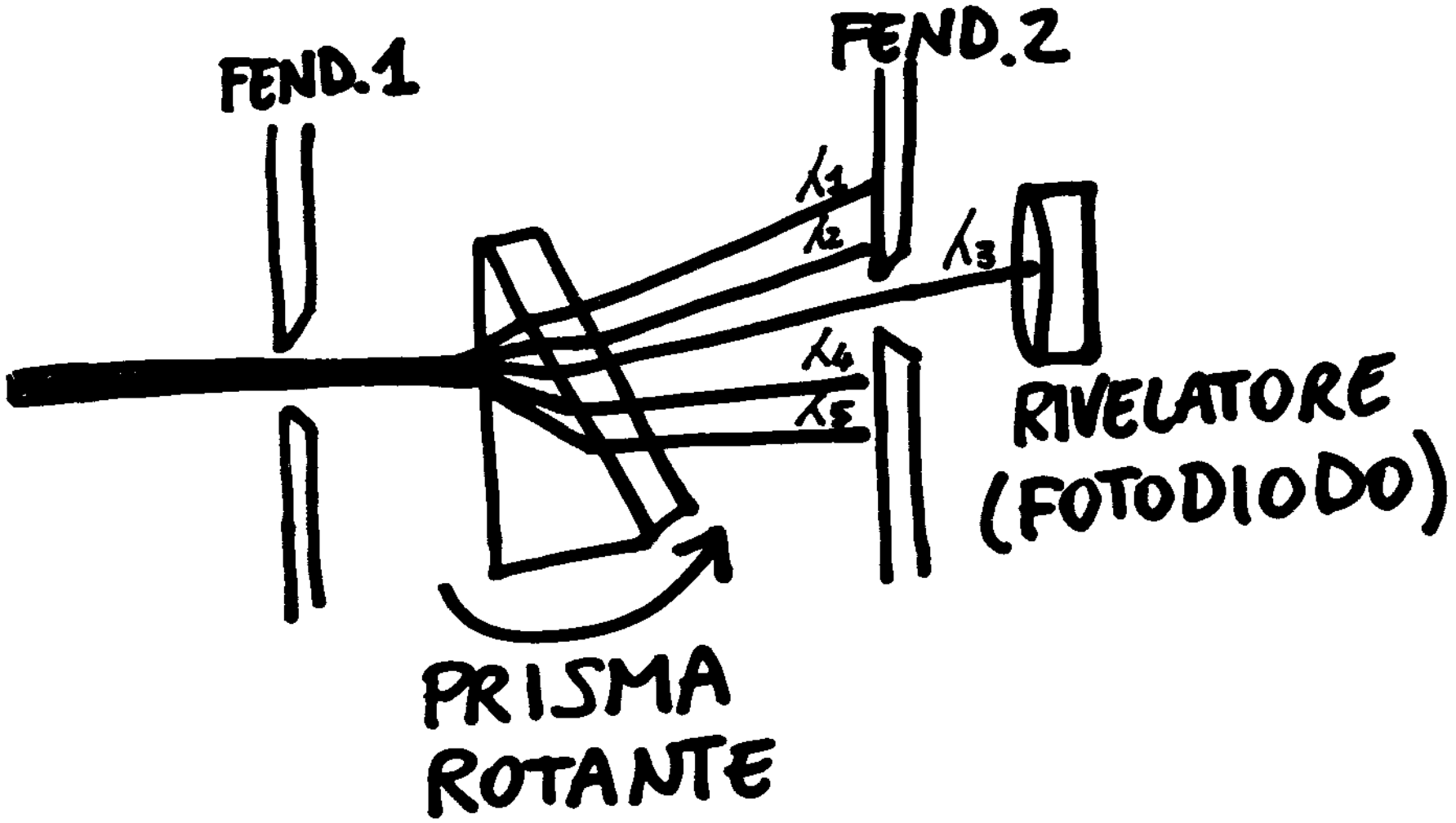
LA VELOCITA' DI SCANSIONE, SS = [Hz/s], E' LIMITATA DA

$$MT \sim \tau \sim \frac{1}{RBW}$$

$$ST = N \times MT \sim \frac{\Delta f_{SPAN}}{(RBW)^2}$$

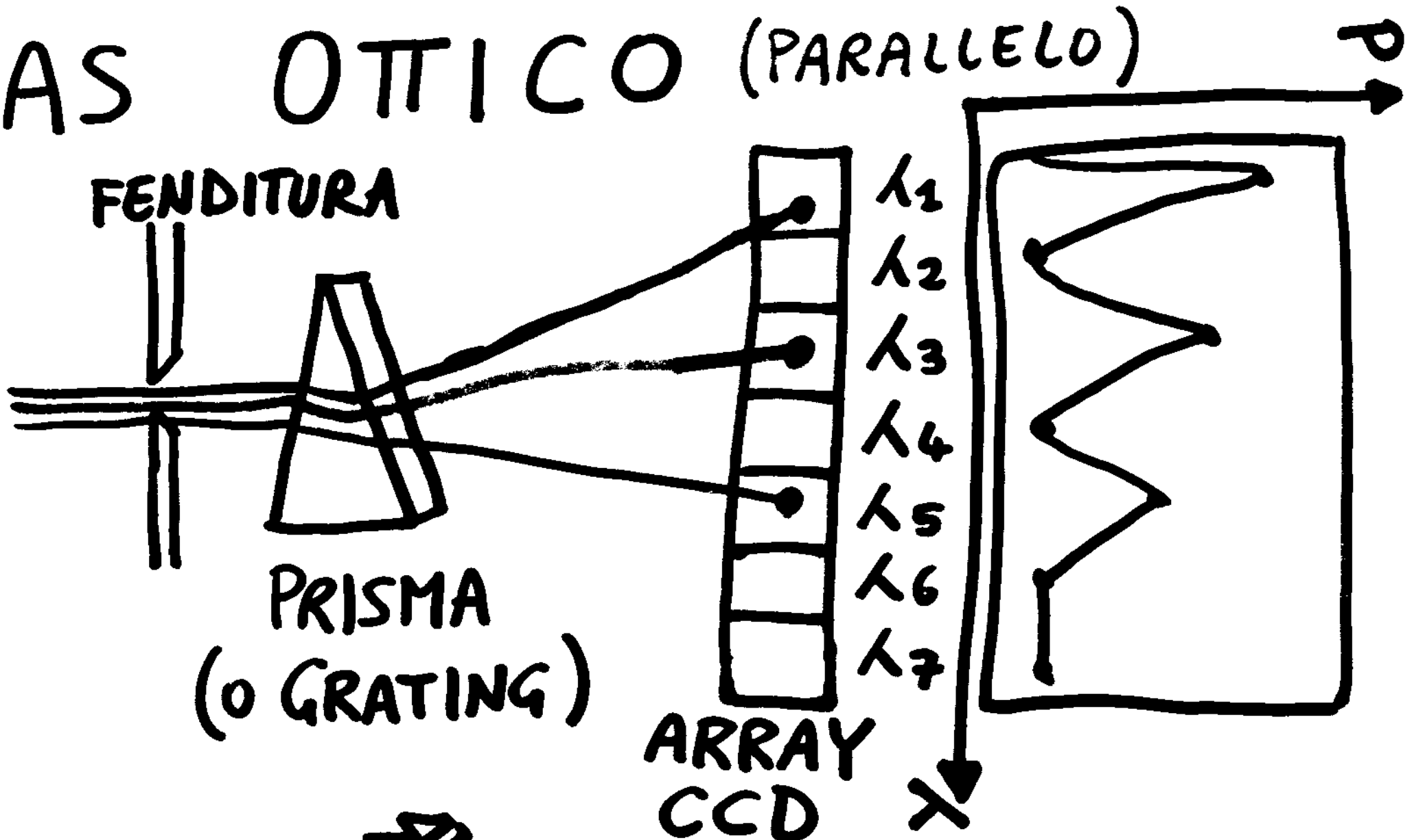
A SPAN FISSATO, IL TEMPO DI SCANSIONE CRESCE QUADRATICAM. AL DIMINUIRE DI RBW

AS OTTICO (SEQUENZIALE)



SI TRASMETTONO IN SUCCESSIONE SU UN UNICO RIVELATORE LE DIVERSE LUNGHEZZE D'ONDA $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$

AS OTTICO (PARALLELO)



ELEMENTO DISPERSIVO CON $\theta = \theta(\lambda)$