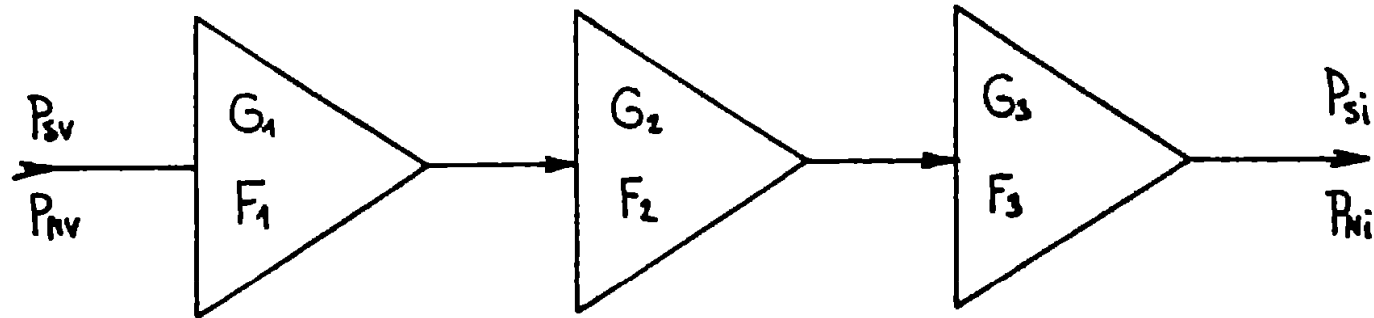


Vrsta ojačevalnika	Ojačenje G [dB]	Šumna temp. T [K]	Šumno število F _{dB} [dB]
Elektronka s kemilno mrežico (trioda, pentoda)	10 ÷ 20	2000 ÷ 9000	9 ÷ 15
Elektronka z modulacijo hitrosti (klistron, TWT)	20 ÷ 50	3000 ÷ 30000	10 ÷ 20
Parametrični ojačevalnik (na sobni temperaturi)	10 ÷ 15	75 ÷ 300	1 ÷ 3
Si bipolarni tranzistor Si MOS FET	10 ÷ 20	75 ÷ 300	1 ÷ 3
GaAs FET HEMT	10 ÷ 15	20 ÷ 120	0.3 ÷ 1.5
MMIC ojačevalnik (Si ali GaAs)	10 ÷ 25	170 ÷ 1600	2 ÷ 8
Operacijski ojačevalnik	60 ÷ 100	10 ⁴ ÷ 10 ⁹	16 ÷ 66



$$T = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \dots$$

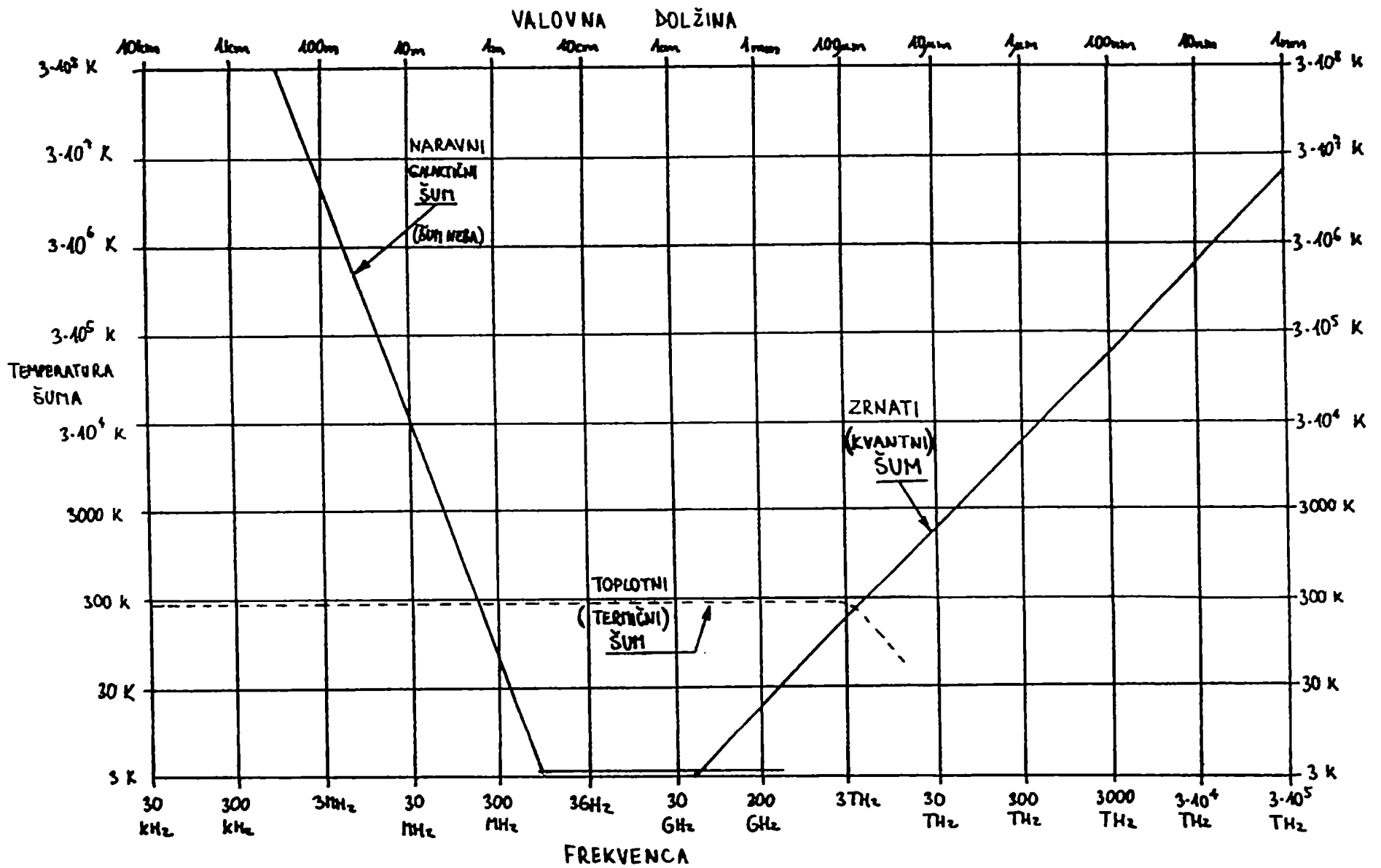
$$F = 1 + \frac{T}{T_0} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \dots$$

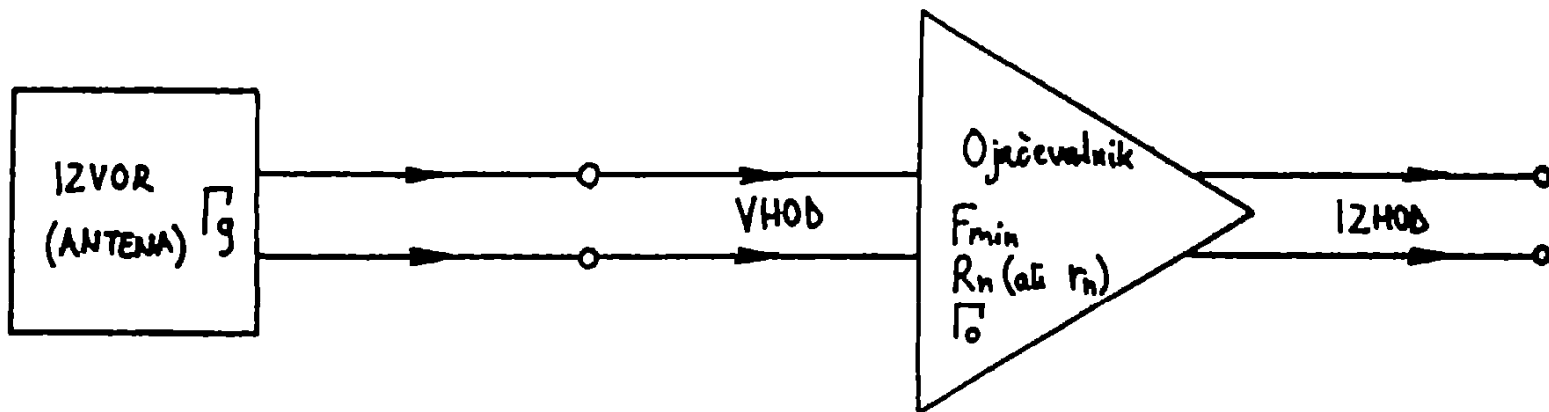
$F_1, F_2, F_3, \dots \equiv$ šumna števila v linearnih enotah moči!

$$F = 10^{\frac{F_{dB}}{10}} ; F_{dB} = 10 \log F$$

Neskončna veriga enakih ojačevalnikov F', G' : $F = 1 + (F' - 1) \cdot \frac{G'}{G' - 1}$

Vrsta šumnega izvora	T_1 (hladno)	T_2 (vroče)	ENR [dB]
Vakuumška šumna dioda	293K	$\sim 10^4$ K (nastavljivo)	~ 15 dB (nastavljivo)
Plinska šumna dioda	293K	$\sim 10^4$ K	~ 15 dB
Plazovna dioda ($U_2 = 18$ V)	293K	$\sim 10^6$ K	~ 36 dB
Hlajeni upor (tekoči N_2)	77 K	293K	-5.8 dB



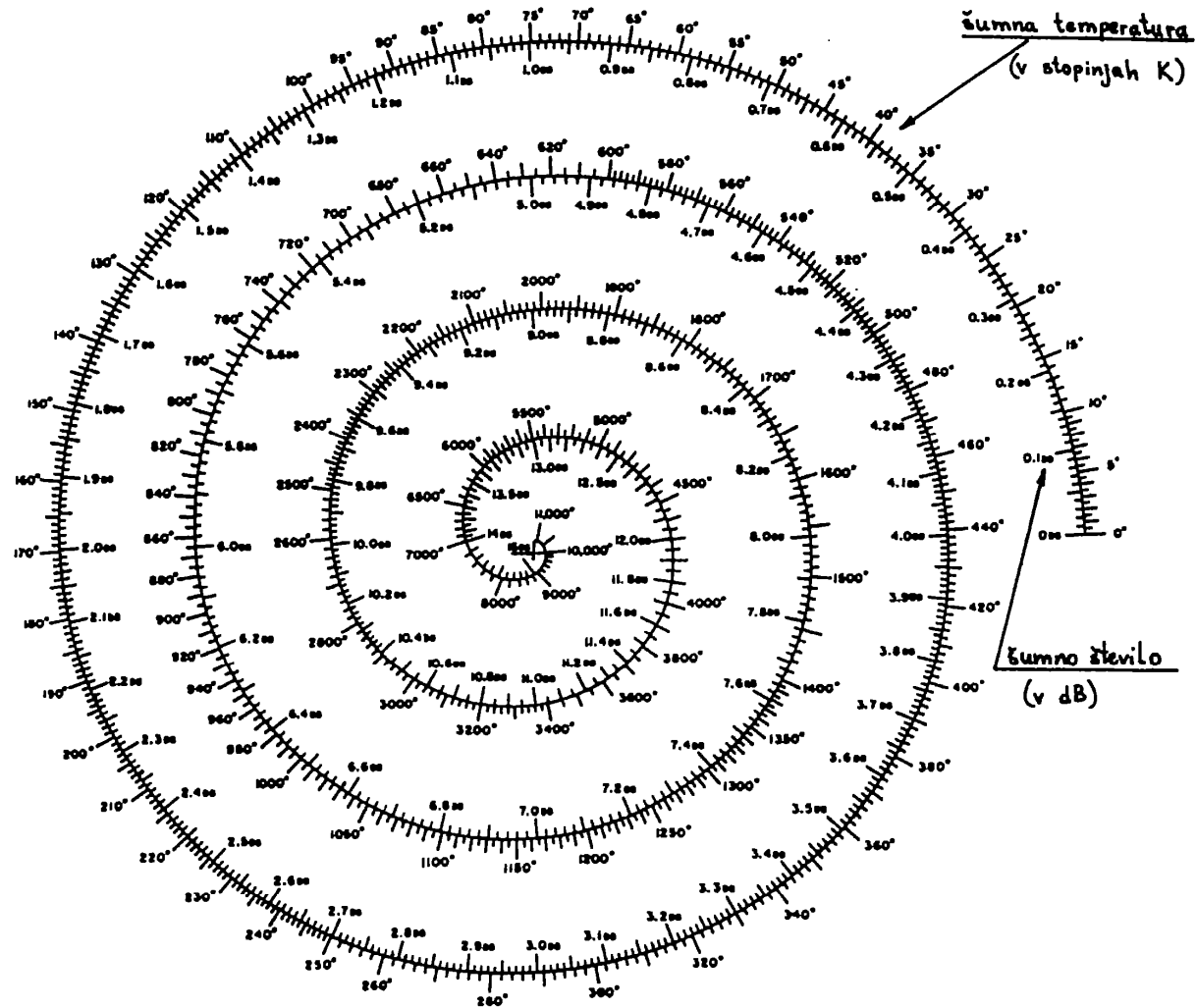


$$F = F_{\min} + 4 \frac{R_n}{Z_k} \cdot \frac{|\Gamma_g - \Gamma_o|^2}{(1 - |\Gamma_g|^2) \cdot |1 + \Gamma_o|^2} = F_{\min} + 4r_n \cdot \frac{|\Gamma_g - \Gamma_o|^2}{(1 - |\Gamma_g|^2) \cdot |1 + \Gamma_o|^2}$$

$F_{\min} \equiv$ najnižje šumno število pri $\Gamma_g = \Gamma_o$, v linearnih enotah (ne v dB!)

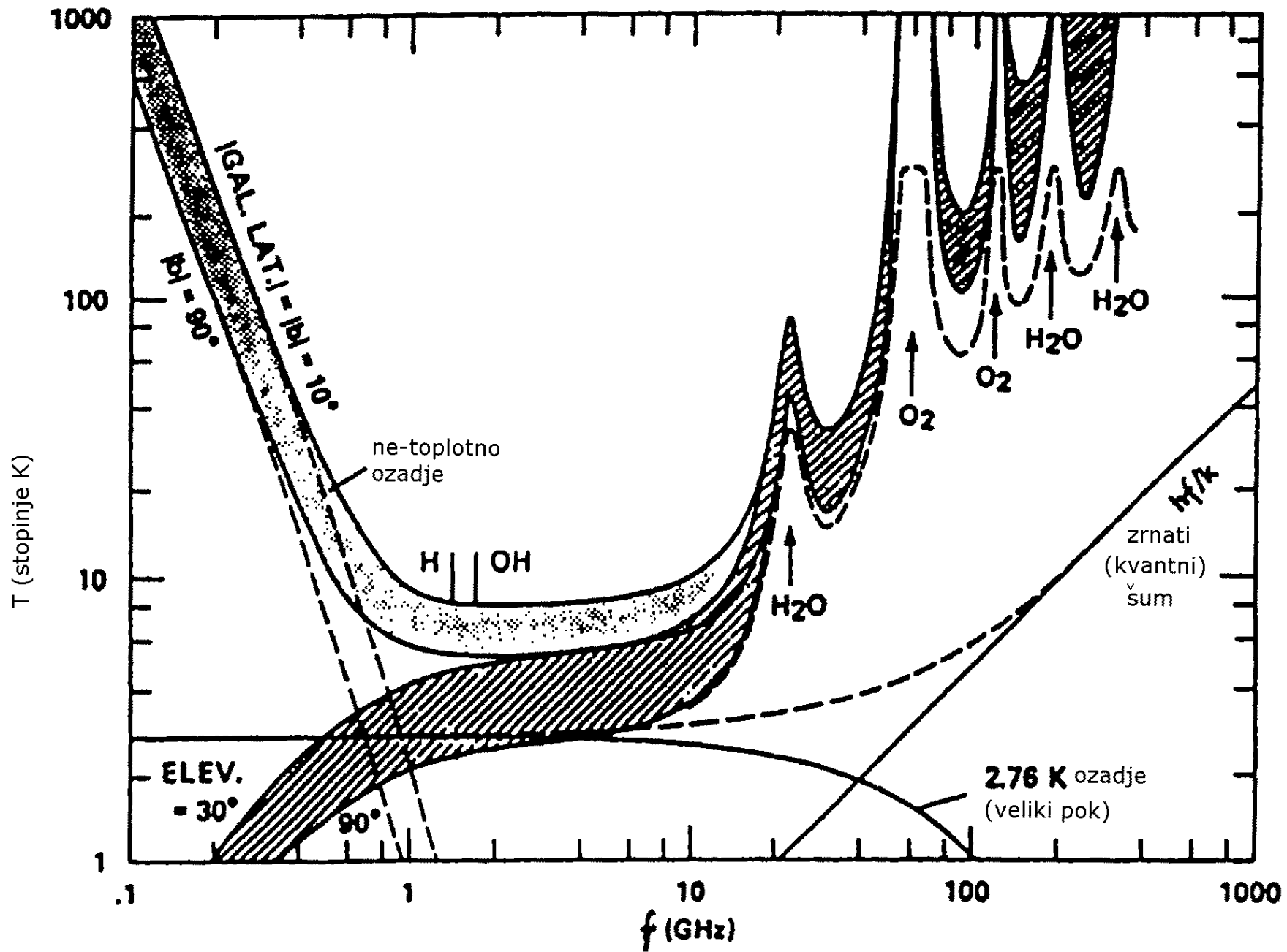
$\Gamma_o \equiv$ optimalna odbojnost izvora za F_{\min}

$r_n = \frac{R_n}{Z_k} \equiv$ normirana šumna upornost (običajno $Z_k = 50 \Omega$)

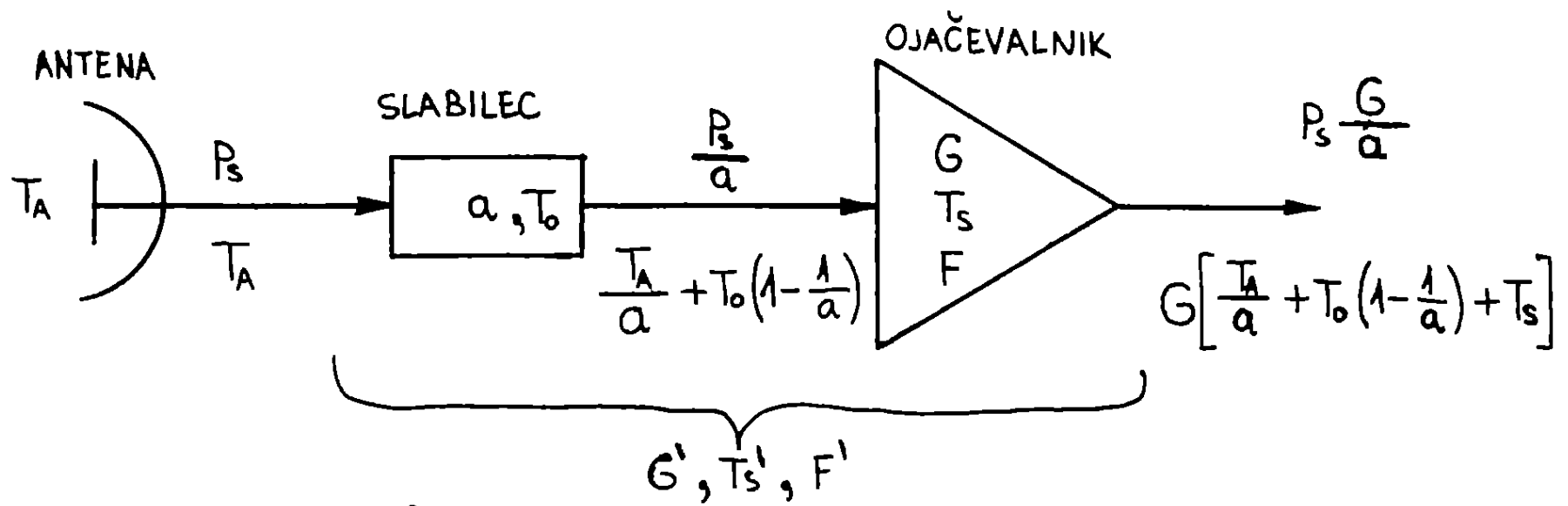


$$F_{dB} [dB] = 10 \cdot \log_{10} \left(1 + \frac{T}{293K} \right)$$

$$T [K] = 293K \cdot \left(10^{\frac{F_{dB}}{10}} - 1 \right)$$



$$\frac{P_s}{P_N} = \frac{P_o \cdot G_o \cdot G_s \cdot \left(\frac{\lambda}{4\pi R}\right)^2}{(T_A + T_s) \cdot k_B \cdot \Delta f} = \frac{P_o \cdot G_o}{k_B \cdot \Delta f} \left(\frac{\lambda}{4\pi R}\right)^2 G_{s/T} \quad ; \quad G_{s/T} = \frac{G_s}{T_A + T_s}$$

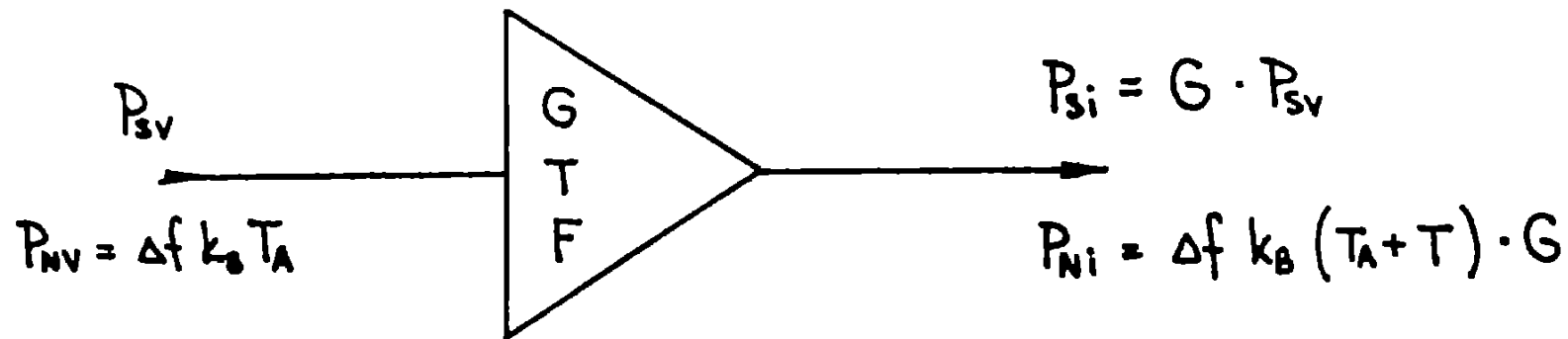


$$\left(\frac{P_s}{P_N} \right)_{\text{12KOB}} = \frac{P_s \frac{G}{a}}{\Delta f k_B G \left[\frac{T_A}{a} + T_0 \left(1 - \frac{1}{a} \right) + T_s \right]} = \frac{P_s}{\Delta f k_B \left[T_A + \underbrace{T_0(a-1) + T_s a}_{T_s'} \right]}$$

$$F' = 1 + \frac{T_s'}{T_0} = 1 + \frac{T_0(a-1) + T_s a}{T_0} = \left(1 + \frac{T_s}{T_0} \right) a = Fa$$

$$F'_{dB} = F_{dB} + a_{dB} \quad G'_{dB} = G_{dB} - a_{dB}$$

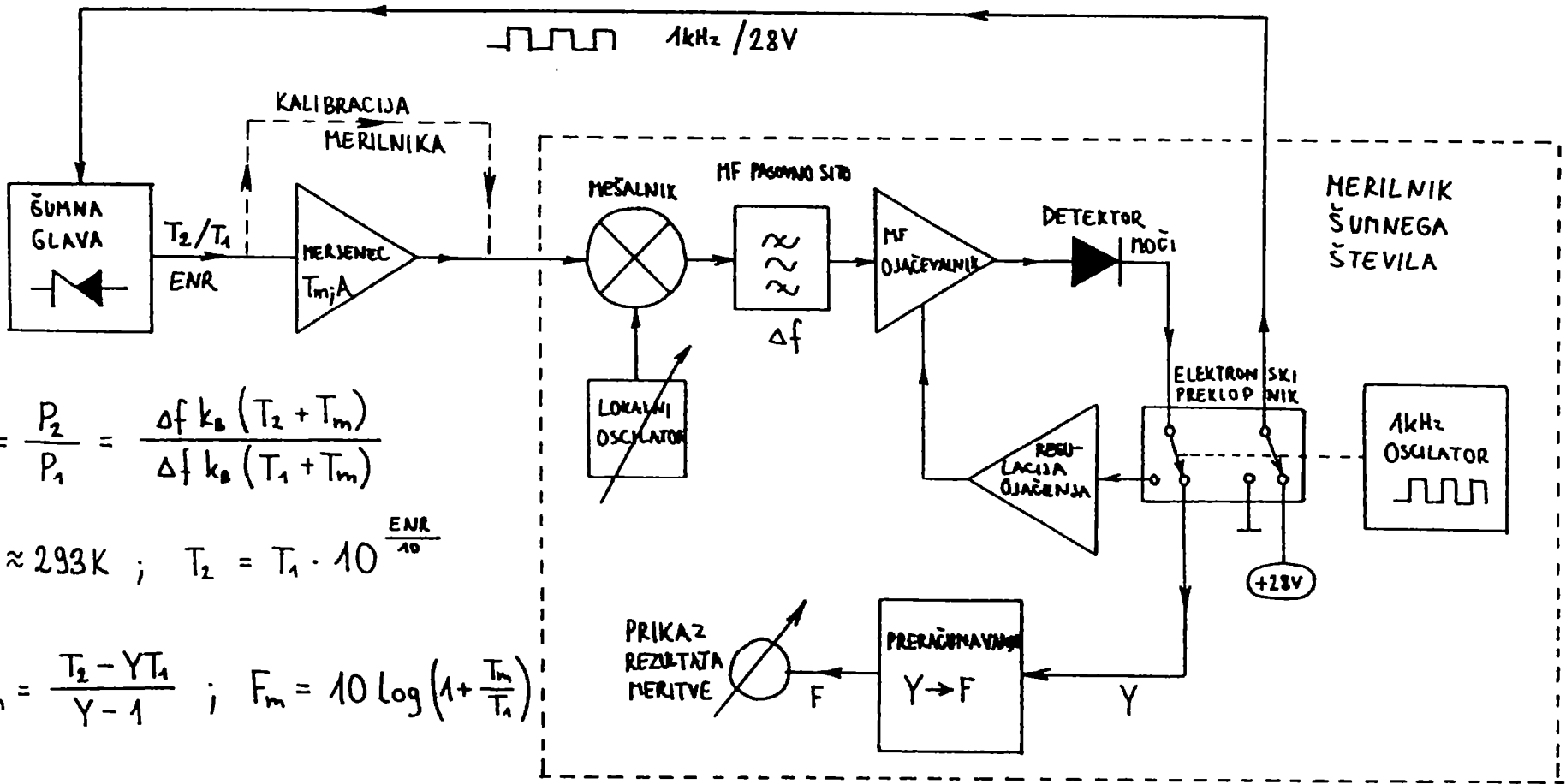
$$T_{\text{ANTENE}} = \frac{\int_{4\pi} T(\theta, \phi) \cdot |F(\theta, \phi)|^2 \cdot d\Omega}{\int_{4\pi} |F(\theta, \phi)|^2 \cdot d\Omega}$$



$$\frac{P_{si}}{P_{ni}} = \frac{T_A}{T_A + T} \cdot \frac{P_{sv}}{P_{nv}} = \frac{1}{1 + \frac{T}{T_A}} \cdot \frac{P_{sv}}{P_{nv}}$$

Definicija: $F = 1 + \frac{T}{T_0}$; $F_{dB} = 10 \log \left(1 + \frac{T}{T_0} \right)$; $T_0 \approx 293 \text{ K}$

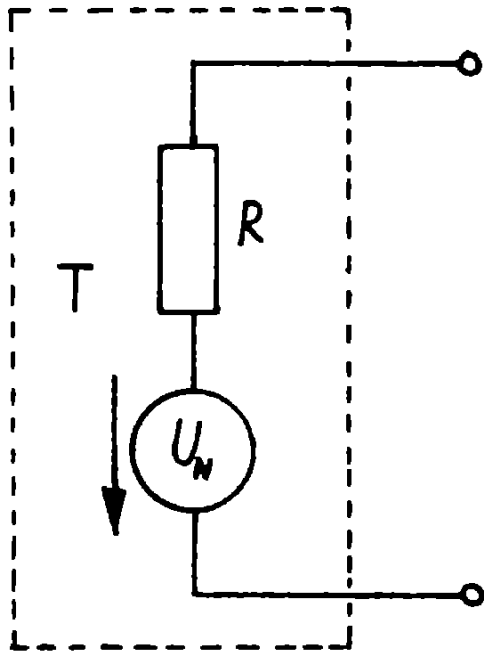
Samo v slučaju $T_A = T_0$ velja: $\frac{P_{si}}{P_{ni}} = \frac{1}{F} \cdot \frac{P_{sv}}{P_{nv}}$



$$Y = \frac{P_2}{P_1} = \frac{\Delta f k_B (T_2 + T_m)}{\Delta f k_B (T_1 + T_m)}$$

$$T_1 \approx 293K ; T_2 = T_1 \cdot 10^{\frac{ENR}{10}}$$

$$T_m = \frac{T_2 - Y T_1}{Y - 1} ; F_m = 10 \log \left(1 + \frac{T_m}{T_1} \right)$$

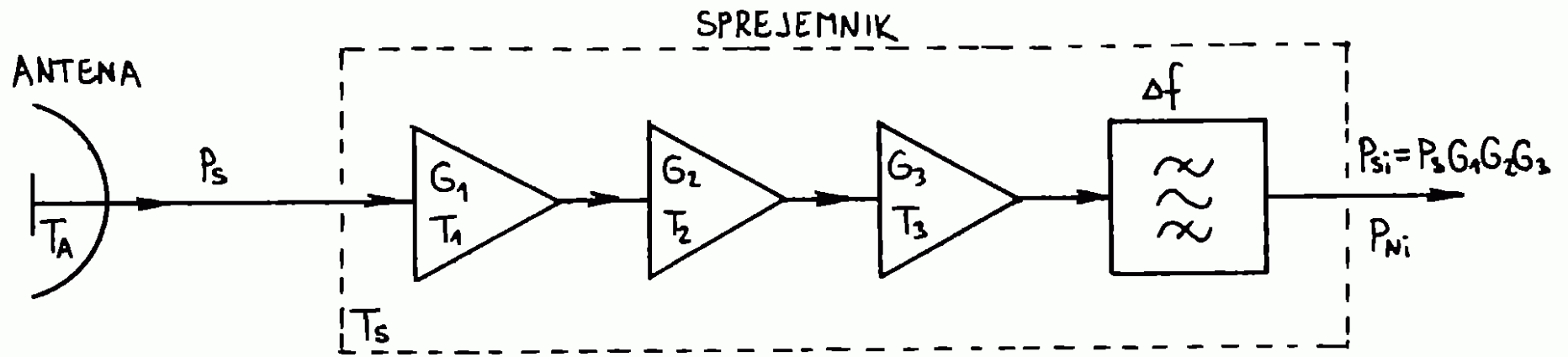


Šumni napetostni izvor:

$$U_N = \sqrt{4 \cdot R \cdot \Delta f \cdot k_B \cdot T} \quad [V_{\text{eff}}]$$

$$k_B = 1.38 \cdot 10^{-23} \text{ J/K} \quad ; \Delta f \equiv \text{pasovna širina}$$

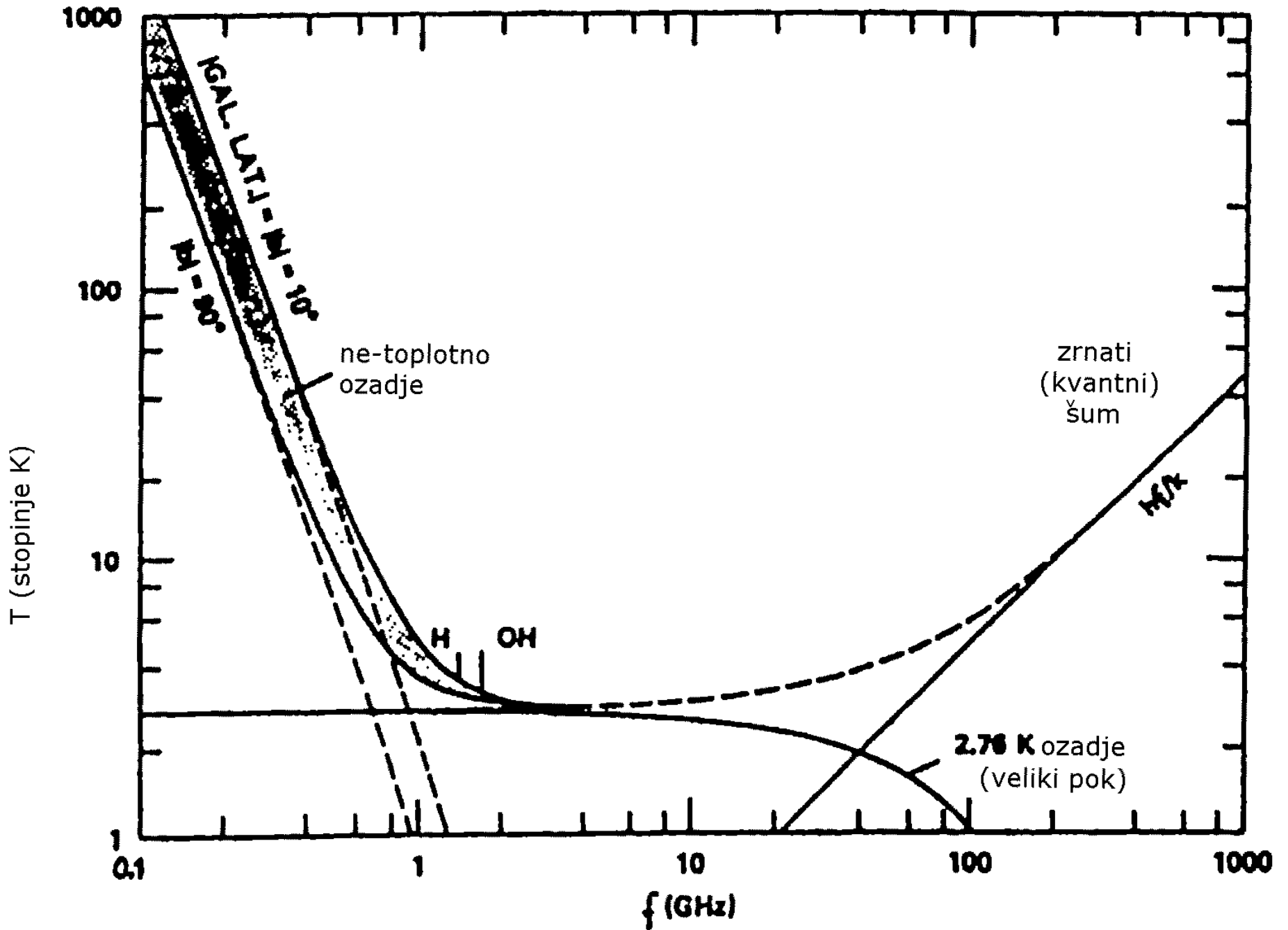
$$P_N = \Delta f \cdot k_B \cdot T \quad (\text{na prilagojenem bremenu})$$

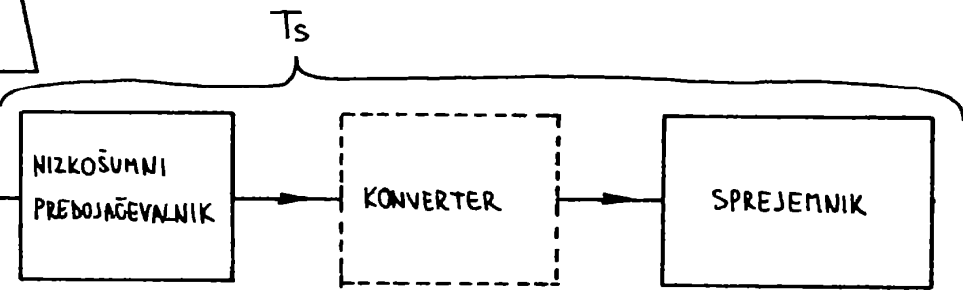
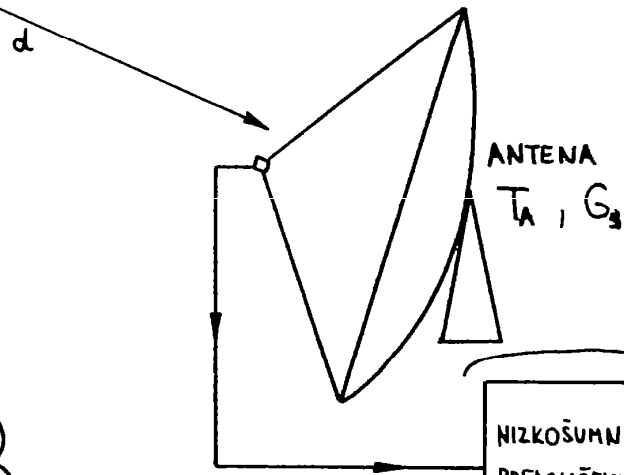
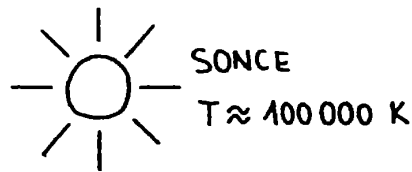
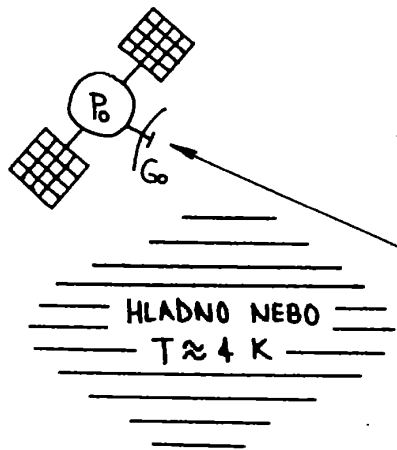


$$\frac{P_{si}}{P_{Ni}} = \frac{P_s G_1 G_2 G_3}{\Delta f k_B (T_A G_1 G_2 G_3 + T_1 G_1 G_2 G_3 + T_2 G_2 G_3 + T_3 G_3)}$$

$$\frac{P_{si}}{P_{Ni}} = \frac{P_s}{\Delta f k_B \left(T_A + T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} \right)}$$

$$T = T_A + T_s \quad T_s = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2}$$





Šumna moč: $P_N = (T_A + T_s) \cdot k_B \cdot \Delta f$

$k_B = 1.38 \cdot 10^{-23} \text{ Ws/K}$ Boltzmannova konstanta

Δf = pasovna širina sprejemnika (sita v medfrekvenci)