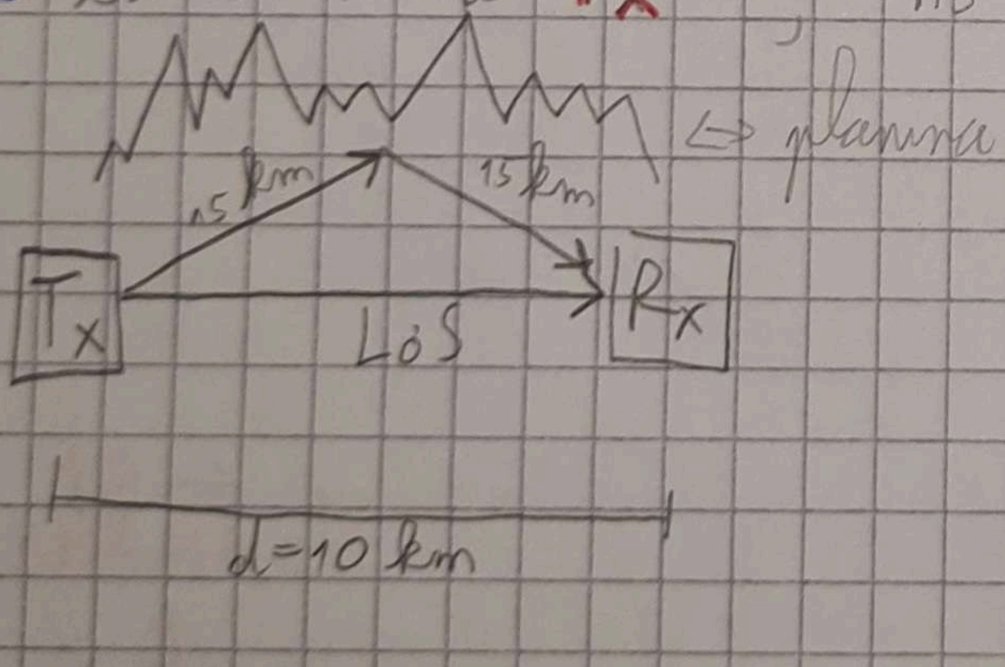
Zadatak

(1) DIREKTNA ZRAKA

BS - bazna stanica $\equiv T_x$; MS - mob. stanica $\equiv R_x$; LoS - LINE OF SIGHT



reflektirana mora doći u $\leftarrow \frac{1}{10}$ trajanja simbola

MODULACIJA? → nije zadano

$LoS = 10\,km$

$d_{REFL.ZRAKE} = 30\,km$

$\Big\} \Delta d = 20\,km$

$$\frac{1000\,m}{3\cdot10^{8}\,m/s} = 3.33\,\mu s$$ (MIKRO) ∀ KILOMETAR

$\lambda = \frac{c}{f}$

$20 \cdot 3.33\,\mu s = 66.67\,\mu s \Rightarrow$ DODATNO KAŠNJENJE ZA 20km

$T < 0.1 \cdot T_s$

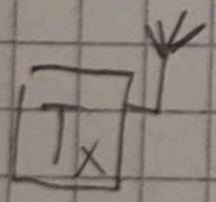
mjet iz zadatka

$R_b = \frac{1}{T_b}$ → ZA BITOVE ; $R_s = \frac{1}{T_s}$ → ZA SIMBOLE

pretp. $\Rightarrow 66.67\,\mu s < 0.1 \cdot T_s \rightarrow T_s > 666.7\,\mu s$

$\rightarrow \frac{1}{T_s} = 1500$ SIMBOL/s (R_s)

SLOBODNO PODRUČJE
↳ nema smetnji u LoS



P_{TX}
↳ snaga

↳ P_{RX}

gain PRIM. ANTENE

Snaga je u W
(ili mW)

$$P_{RX} = P_{TX} G_{TX} G_{RX} \cdot \left(\frac{\lambda}{4\pi d}\right)^2$$

↳ GUBITAK U SLOB. PROSTORU

SNAGA ODAŠILJ. ANTENE

DOBITKA ODAŠILJ. ANTENE

decibeli (· → + ; : → −) ⇒ govore onjine

② FRISSOVA FORMULA

$$P_{Rx}\,[dBm] = P_{Tx}\,[dBm] + G_{Tx}\,[dB_i] + G_{Rx}\,[dB_i] + 10\log_{10}\left(\frac{\lambda}{4\pi d}\right)^2$$

$$20\log\left(\frac{\lambda}{4\pi d}\right)$$

2 PRIJAMNIKA

Z: 0.1 μW
Y: −103 dBm

} OSJETLJIVOSTI PRIJAMNIKA

⇒ svedi na iste jedinice

OSJETLJIVIJI prijamnik signal manje slabe

$0.1\,\mu W = 10\log(0.1 \cdot 10^{-3}\,W)$

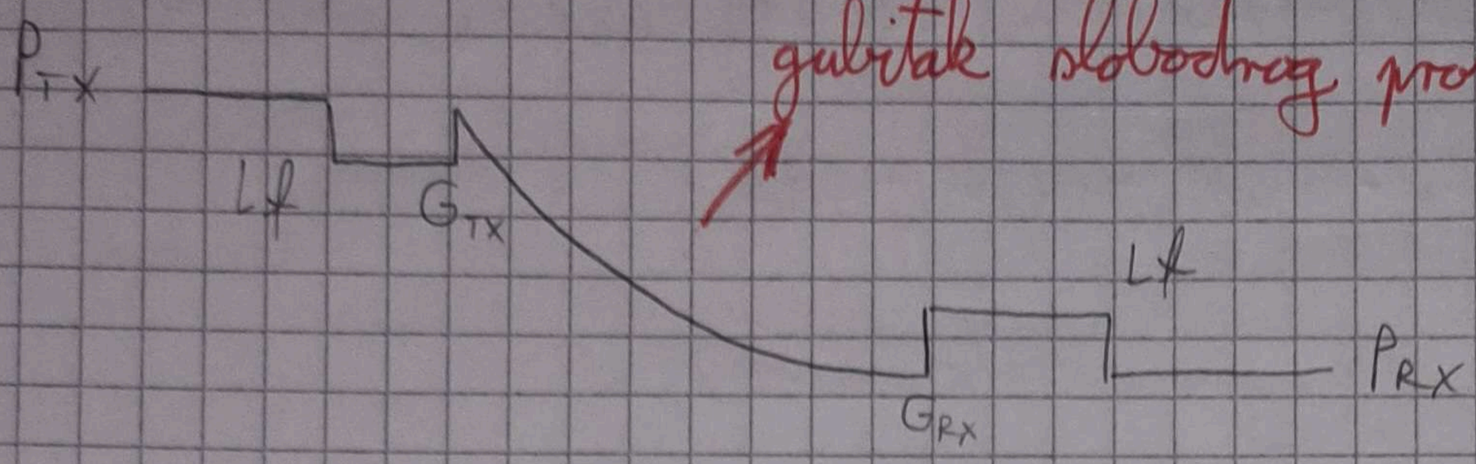
$= -130\,dBW$

$Z \Rightarrow -100\,dBm$

OSJETLJIVOST

dBW —(+30, jer)→ dBm

30 dB ↑ W = 1000 mW



C... carrier/nosilac

N... noise

---

① d=5km veza, 1 AP, 1 uređaj (KLIJENTSKI)

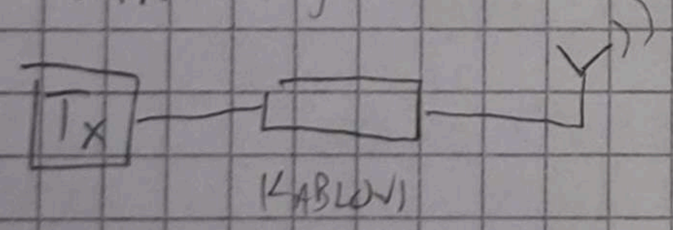
$10dBi = G_{TX}$ $P_{TX} = 20dBm$ osjetljivost = -89 dBm ← AP

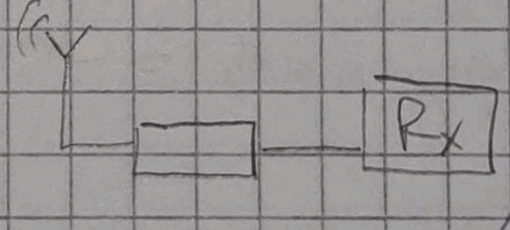
$14dBi = G_{RX}$ $P_{TX} = 15dBm$ osjet = -82 dBm ← KLIJENTI

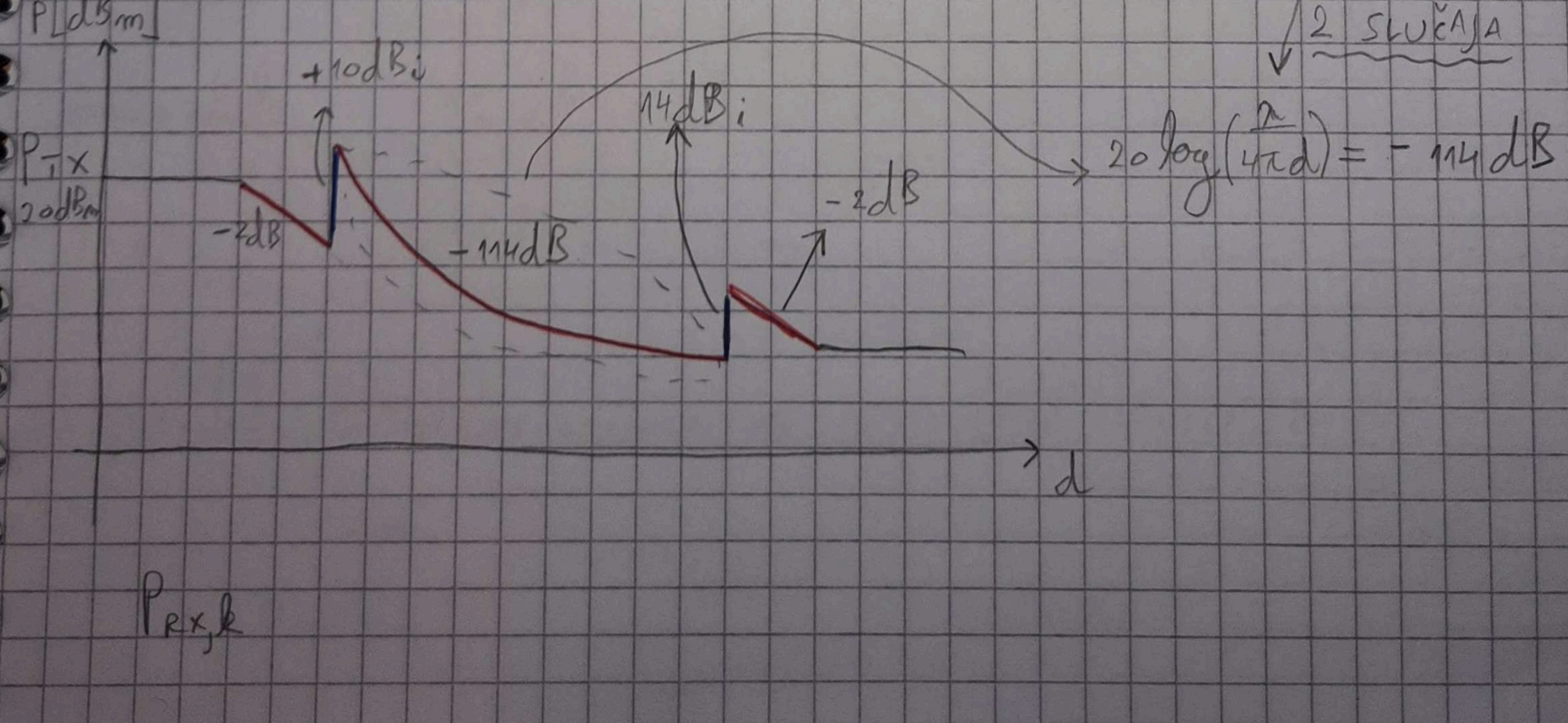
2dB GUBITAK KABELA ; $f = 2.4\ GHz \rightarrow \lambda = \frac{c}{f}$, $d = 5000\ m$

OSTVARIVOST VEZE ?

1) AP → Tx KLIJENT → Rx







2 SLUČAJA

$20\log\left(\frac{\lambda}{4\pi d}\right) = -114\ dB$

$$P_{Rx}[dBm] = P_{Tx}[dBm] + G_{Tx}[dBi] + G_{Rx}[dBi] + 20\log\left(\frac{\lambda}{4\pi d}\right)\left(\begin{matrix}\text{razni na}\\ \text{gubitke}\end{matrix}\right)$$

$$P_{Rx,k} = 20dBm - 2dB + 10dBi - 114dB + 14dBi - 2dB$$

$$= \underline{-74\,dBm}$$ (ovo je veće pa možete koristiti)

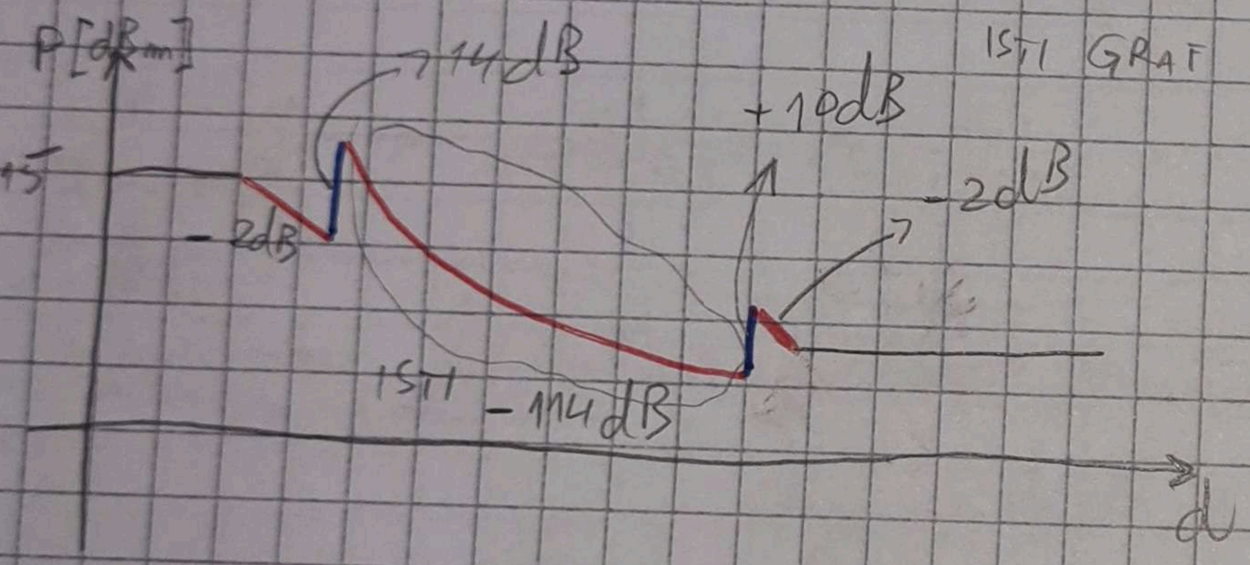
od

↓

OSJETLJIVOST KLIJENTA je gleda → $-82\,dBm$

↳ marginа linka iznosi: $\underline{8\,dB}$

2) KLIJENT → T_x , AP → R_x



$$P_{Rx,AP} = 15dBm - 2dB + 14dBi - 114dB + 10dBi - 2dB$$

$$= -79\,dBm$$

OSJETLJIVOST (AP-a) prijamnika $= -89\,dBm$

OSTVARIVO JER

$-79 > -89\,dBm$

margina je 10dB

② ODAŠILJAČ

PRIJAMNIK

$L_{LOS} = ?$, (prije i nakon točke prekida)

nakon nje Friisov zakon ne vrijedi

margina - linka = 12 dB, točka prekida = 100 m

$f = 950$ MHz ; osjetljivost $= -102$ dBm, $P_{Tx} = 30$ W, $G_{Tx} = 10$ GUBITCI KABELA

$L_f = 5$ dB

Tx

[dB]

10 log(30)

dBm

dB

P_{Tx} 30W $(15 + 30) = 45$ dBm

G_{Tx} 10 10 dB

L_f -5 dB

50 dBm ⟶ EIRP

Rx

OSJETLJIVOST -102 dBm

marginalinka 12 dB

P_{Rx} -90 dBm

⟶ gubitak slobodnog prostora → $50 - (-90) = 140$ dB

L_{LOS}

do točke prekida $d = 100\,m$

$$20 \log \leftrightarrow \left(\frac{\lambda}{4\pi d}\right) \Rightarrow -72\,dB$$

$140 - 72 = 68$

nakon točke prekida → 68 dB (razlika u odnosu na 140 dB)

③

$$R_2 = \frac{2 D_A^2}{\lambda}$$

RAYLEIGHOVA UDALJENOST

(daleko polje)

→ kvadratna antena: $G = 20\,dB$

efektivna površina antene

$$A_{Rx} = A_e = A_r$$

gustoća snage na površini

$$\frac{P_{Tx}}{4\pi d^2}$$

$$\text{-II-} \cdot A_e = \text{PRIJAMNA SNAGA}$$

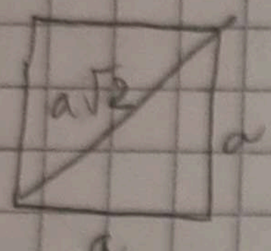
$$P_{Rx} = \frac{P_{Tx} \cdot G_{Tx}}{4\pi d^2} \cdot A_{Rx}$$

$A_e = \frac{\lambda^2}{4\pi} \cdot G_{Rx} = \lambda^2 \cdot 100 \cdot \frac{1}{4\pi} = \underbrace{8\lambda^2}_{} = A_e$

$G = 20\,dB \rightarrow$ apsolutne jedinice

$\underline{G = 100}$

$R_2 = \frac{2 \cdot D_A}{\lambda}$



površina kvadrata $\rightarrow P = a^2 = 8\lambda^2$

$\boxed{a = 2\sqrt{2}\lambda}$

dijagonala

$\hookrightarrow d = a\sqrt{2} = 2\sqrt{2} \cdot \lambda\sqrt{2} = 4\lambda$ dijagonala

$R_2 = \frac{2 \cdot (4\lambda)^2}{\lambda} = \textcircled{32\lambda}$ rješenje udaljenost od koje vrijedi FRIISOV zakon

POVRŠINA

N1

(4)

$A_{Rx} = 0.55\,\textcircled{A} \rightarrow$ kružna antena $\rightarrow$ površina otvora $\pi^2\pi$

dobitak = ? $\rightarrow$ U ODNOSU NA IZOTROPNI RADIJATOR

$A_{ISO} = \frac{\lambda^2}{4\pi}$ $\quad G = \frac{A_{Rx}}{A_{ISO}} = \frac{0.55A}{\frac{\lambda^2}{4\pi}} = \frac{4\pi}{\lambda^2} = 0.55 \cdot \pi^2\pi$

$\boxed{G = 2.2 \cdot \frac{\pi^2 \cdot \pi^2}{\lambda}}$

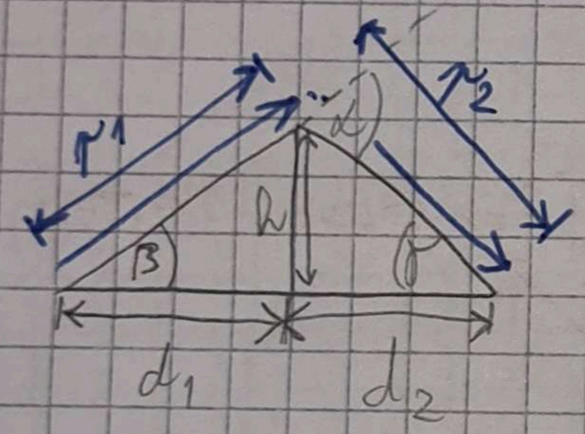
① prema crtežima izvedi formule

a) RAZLIKA FAZA PUTANJA

$$\Theta_\Delta = \frac{2\pi}{\lambda}\Delta = \frac{2\pi}{\lambda}\cdot\left[\frac{d^2}{2}\cdot\left(\frac{d_1+d_2}{d_1 d_2}\right)\right]$$

b) $$v = d\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2)}} = h\cdot\sqrt{\frac{2}{\lambda}\cdot\frac{d_1+d_2}{d_1d_2}}$$

a)



$$r_1 = \sqrt{d_1^2 + h^2}$$

$$r_2 = \sqrt{d_2^2 + h^2}$$

aproksimacija ⇒

APROKSIMACIJA KORIJENA

$$\sqrt{1+e} = 1 + \frac{1}{2}e \quad / ^2$$

$$1+e = 1 + e + \frac{1}{4}e^2$$

ako $e \ll$, zanemarimo e^2

(vrijedi i za $\frac{x}{d}$, bilo što)

$$r_1 = d_1\cdot\sqrt{1+\left(\frac{h}{d_1}\right)^2}$$

$$r_2 = d_2\cdot\sqrt{1+\left(\frac{h}{d_2}\right)^2}$$

T.J. $d_1, d_2 \gg h$

$$r_1 = d_1\left(1+\frac{1}{2}\left(\frac{h}{d_1}\right)^2\right)$$

$$r_2 = d_2\left(1+\frac{1}{2}\left(\frac{h}{d_2}\right)^2\right)$$

$$\Delta \Rightarrow r_1 + r_2 - d = r_1 + r_2 - (d_1+d_2)$$

$$= d_1\left(1+\frac{1}{2}\left(\frac{h}{d_1}\right)^2\right) + d_2\left(1+\frac{1}{2}\left(\frac{h}{d_2}\right)^2\right) - (d_1+d_2)$$

$$\Delta = \frac{h^2}{2}\cdot\frac{d_1+d_2}{d_1d_2}$$

FRESNELOV PARAM

$$\theta = \frac{v^2 \pi}{2} \qquad v^2 = \sqrt{\frac{2}{\pi} \cdot \theta} = \sqrt{\frac{2}{\pi} \cdot \frac{2\pi}{\lambda} \cdot \frac{h^2}{2} \cdot \frac{d_1+d_2}{d_1 d_2}}$$

$$= h \cdot \sqrt{\frac{2}{\lambda} \cdot \frac{d_1+d_2}{d_1 d_2}}$$

približno
$d_1, d_2 \gg h$

$$tg\,\beta = \frac{h}{d_1} \ll 1 \qquad tg\,\gamma = \frac{h}{d_2} \ll 1$$

$$tg\,\beta \approx \beta \qquad tg\,\gamma \approx \gamma \qquad \Rightarrow \alpha = \beta + \gamma \Rightarrow \alpha = \frac{h}{d_1} + \frac{h}{d_2} = \frac{h(d_1+d_2)}{d_1 d_2}$$

$$h = \alpha \frac{d_1 d_2}{d_1+d_2} \Rightarrow v = h \cdot \sqrt{\frac{2}{\lambda} \cdot \frac{d_1+d_2}{d_1 d_2}} = \alpha \cdot \sqrt{\frac{2}{\lambda} \cdot \frac{d_1 d_2}{d_1+d_2}}$$

UBACI

11.4.2024.

6. tjedan - AUDITORNE

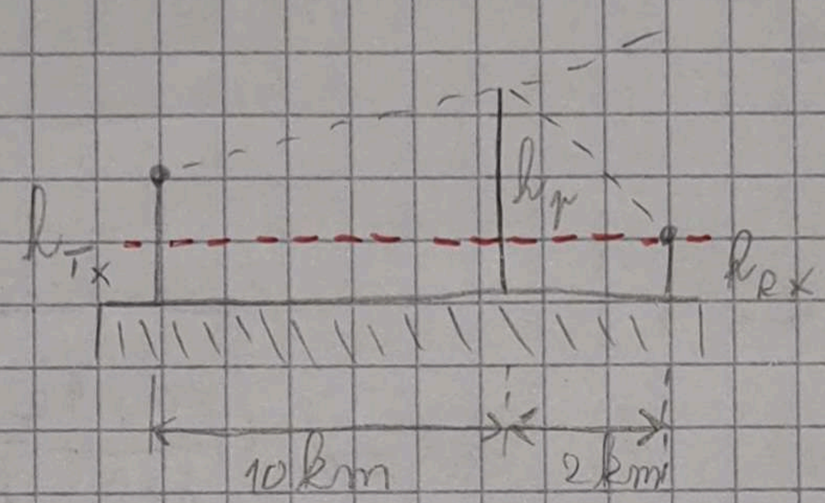
model oštrice noža i model 2 zrake

1) ODAŠILJAČ

PRIJAMNIK

DIFRAK. GUBITAK?

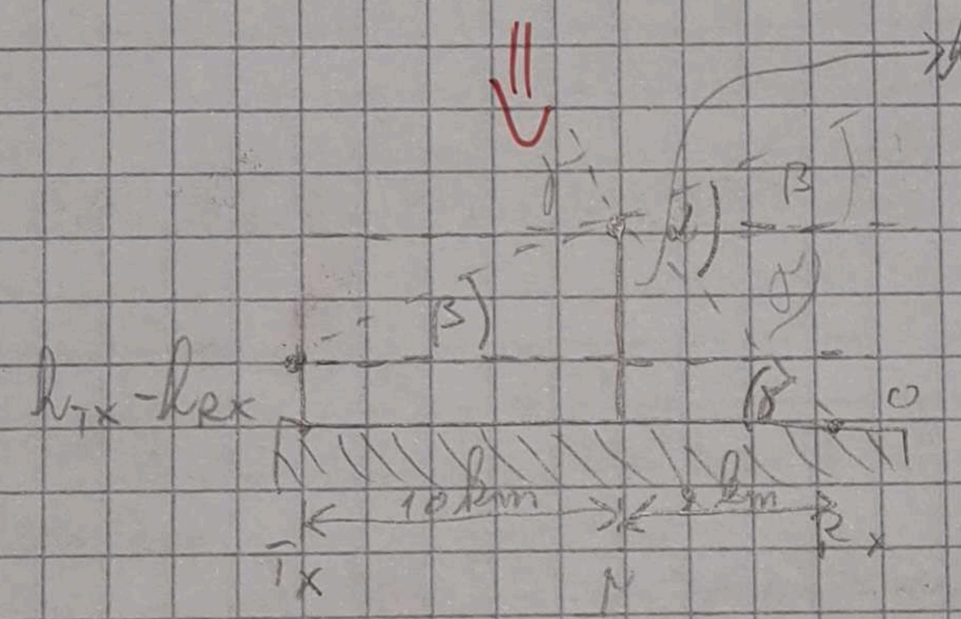
→ G_d (dB) = ?



$h_{Tx} = 50m$

$h_{Rx} = 25m$

$h_P = 100m$



$\alpha = \beta + \delta$

$\alpha = 2.434°$

$\alpha = 0.0424$ rad

$h_T' = 50m - 25m = \underline{25m}$

$h_P' = 100m - 25m = \underline{75m}$

TABLICA OVISI O ν (FRESNELOV PARAM.)

APPROKS. $\beta = \arctan\left(\frac{h_P' - h_{Tx}'}{10km}\right) \overset{tg^{-1}}{\approx} \arctan\left(\frac{75-25\,m}{10\,000\,m}\right) = \underline{0.286°}$

$h_T, h_R, h_P \ll d_1, d_2$

$\gamma = \arctan\left(\frac{h_P'}{2km}\right) = \arctan\left(\frac{75\,m}{2000\,m}\right) = \underline{2.15°}$

$$\nu = \alpha\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2)}} = 4.24$$

$$G_d(dB) = 20\log\left(\frac{0.225}{\nu}\right) = -25.5\,dB$$

$\lambda \Rightarrow f = 900\,MHz$

$\lambda = \frac{3\cdot10^8\,m}{900\cdot10^6} =$

formula gdje je $\nu = 4.24$

$\Delta = \frac{m\lambda}{2}$; problem je n nepoznat

$$\nu = \alpha\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2)}} = h\sqrt{\frac{2(d_1+d_2)}{\lambda(d_1\cdot d_2)}}$$

② OPET DIFRAKCIJA GUBITAK

$\lambda = \frac{1}{3}\,m$; $d = 2\,km$; NADI FRESNELOVU ZONU I IZRAČUNAJ

a) $h = 25\,m$

$$\nu = h\sqrt{\frac{2(d_1+d_2)}{\lambda(d_1d_2)}}$$

$$= 25\cdot\sqrt{\frac{2(1000+1000)}{\frac{1}{3}(1000\cdot1000)}}$$

$\nu = 2{,}74$

$$G_d(dB) = 20\log\left(\frac{0.225}{2.74}\right)$$

$$= -21.71\,dB$$

$$\Delta = \frac{h^2}{2}\cdot\frac{(d_1+d_2)}{d_1\cdot d_2}$$

$\Delta = 0.625\,m$

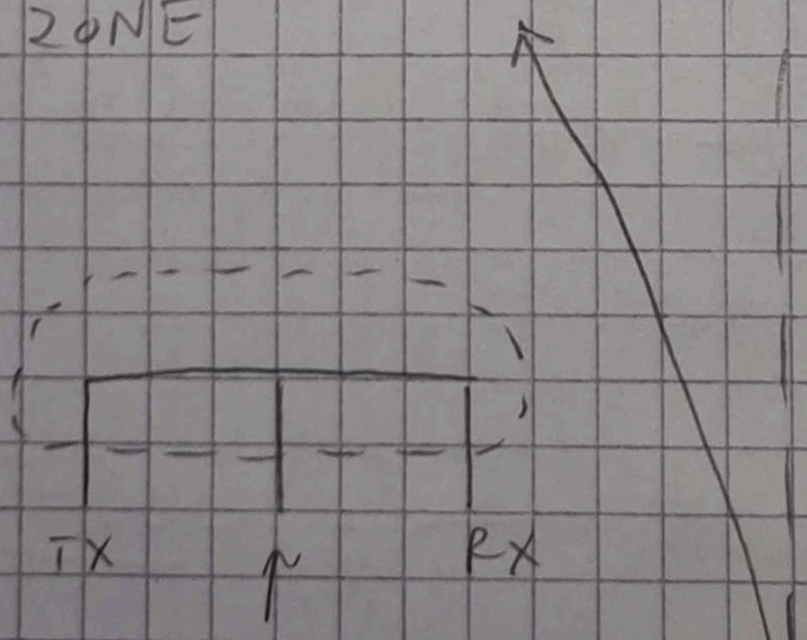
b) $h = 0\,m$

$\Rightarrow \nu = 0$

$$G_d(dB) = 20\log(0{,}5 - 0.62\nu)$$

$$= -6\,dB$$

VRH PREPREKE JE U SREDINI 1. FRESNELOVE ZONE

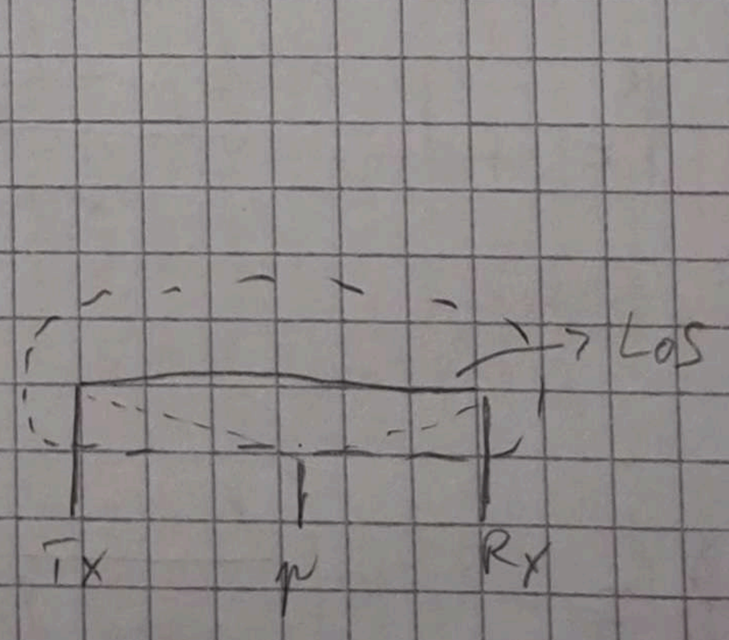


- jer je prepreka na istoj visini kao Tx i Rx pa ne smeta i zato

c) $h = -25\,m$

$\nu = \ldots = -2{,}74$

$G_d(dB) = 0$



- nema gubitka zbog difrakcije

$$\Delta = 0{,}625_m = \frac{m\lambda}{2}$$

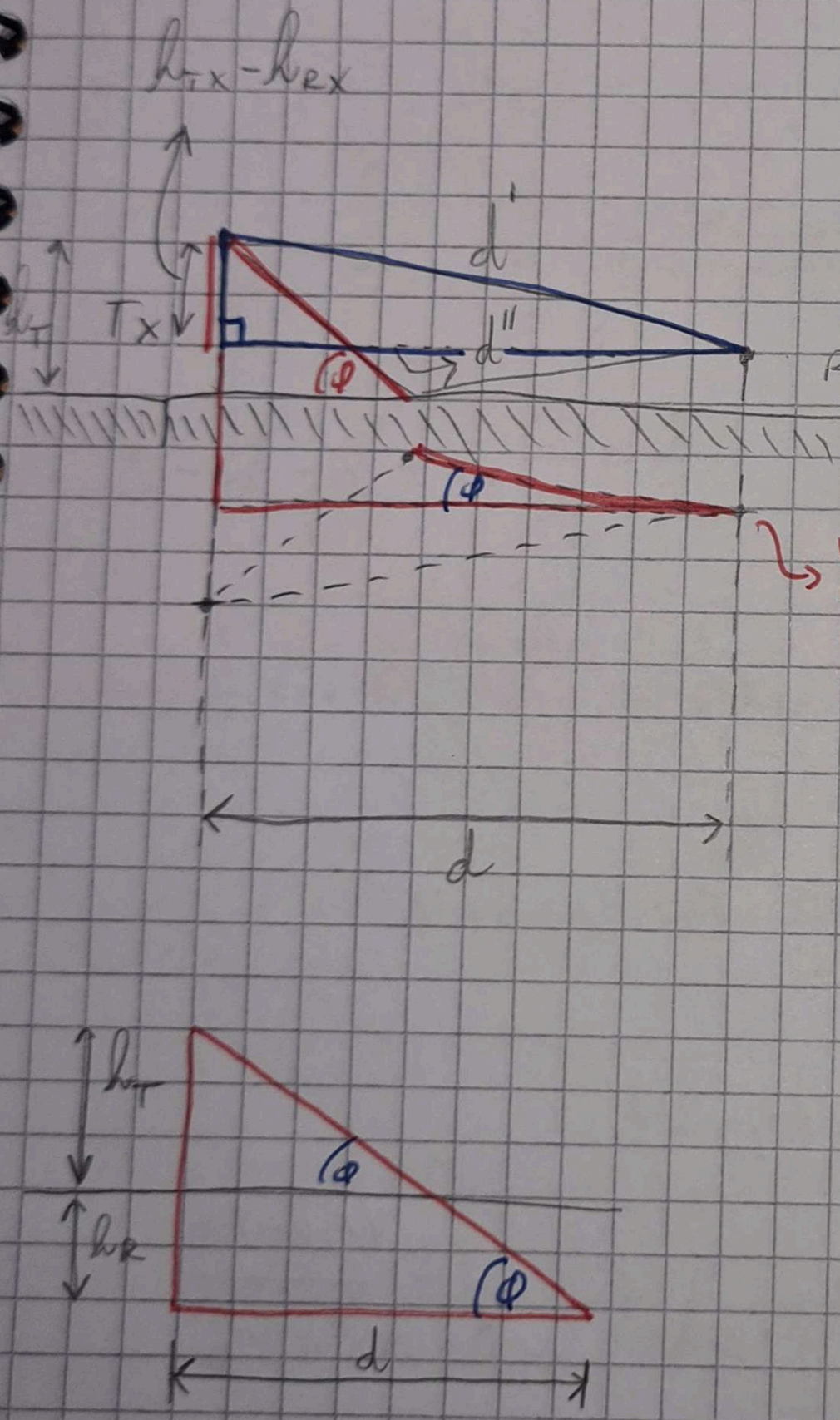
$$m = 3{,}75$$

odstupa

- NJEZIN VRH BLOKIRA PRVE 3 FRESNELOVE ZONE

model 2 zraka

1 ta isti signal putuje 2 razl. putanja



$$\Delta = d'' - d'$$

$$d' = \sqrt{d^2 + (h_{Tx} - h_{Rx})^2}$$

$$d'' = \sqrt{d^2 + (h_{Tx} + h_{Rx})^2}$$

$$\Delta = \sqrt{(h_{Tx} + h_{Rx})^2 + d^2} - \sqrt{(h_{Tx} - h_{Rx})^2 + d^2}$$

③ Dokaži

$$\Delta = d'' - d' = \frac{2 h_{Tx} h_{Rx}}{d}$$

pretp. koje vrijede:

1 - $h_{Tx} h_{Rx} >> \lambda$

2 - $d >> h_{Tx}, h_{Rx}$

3 - POVRŠINA ZEMLJE je ravna

$$\Delta = \sqrt{(h_T + h_R)^2 + d^2} - \sqrt{(h_T - h_R)^2 + d^2}$$

$$= d\left[1 + \left(\frac{h_T + h_R}{d}\right)^2\right]^{\frac{1}{2}} + d\left[1 + \left(\frac{h_T - h_R}{d}\right)^2\right]^{\frac{1}{2}}$$

$$\sqrt{1+x} = \left(1 + \frac{1}{2}x\right)^2$$

$$1 + x = 1 + x + \frac{1}{4}x^2 \qquad x << 1$$

$$\Rightarrow \text{vrijedi} \quad \left(\frac{h_T + h_R}{d}\right)^2 << 1 \;;\; \left(\frac{h_T - h_R}{d}\right)^2 << 1$$

$$\Delta \approx d\left[1 + \frac{1}{2}\left(\frac{h_T + h_R}{d}\right)^2\right] - d\left[1 + \frac{1}{2}\left(\frac{h_T - h_R}{d}\right)^2\right]$$

$$\Delta \approx d \cdot \frac{1}{2} \cdot \frac{4 h_T \cdot h_R}{d^2} = \frac{2 h_T h_R}{d}$$

④ $h_{Rx} = 2m$

$\varphi = 5°$

$\varphi_\Delta = 6.261\ rad$

FAZNA RAZLIKA

$f = 900 MHz \rightarrow \lambda = \frac{1}{3}$

$d = ?$

$h_{Tx} = ?$

$$\Delta \approx \frac{2 h_{Tx} h_{Rx}}{d}$$

$$= d'' - d'$$

$$\varphi_\Delta = \frac{2\pi}{\lambda} \cdot \Delta = \frac{2\pi}{\lambda} \cdot \frac{2 h_T h_R}{d}$$

$$d = \frac{4\pi h_T h_R}{\lambda \varphi_\Delta}$$

$$\varphi = tg\left(\frac{h_{Tx} + h_{Rx}}{d}\right)$$

$$tg\,5^\circ = \frac{h_T + h_R}{d} = \frac{\frac{h_T + h_R}{\lambda\Theta_\Delta}\cdot R_T}{\frac{4\pi h_T h_R}{\lambda\Theta_\Delta}\cdot R_T} = \frac{1 + \frac{h_R}{h_T}}{\frac{4\pi h_R}{\lambda\Theta_\Delta}} \Rightarrow \boxed{\frac{h_R}{h_T} = tg\,5^\circ \cdot \frac{4\pi h_R}{\Theta_\Delta \cdot \lambda} - 1}$$

$$h_T = \frac{h_R}{\frac{4\pi h_R}{\lambda\Theta_\Delta} - 1} = \underline{37{,}32\,m} \rightarrow \text{uvrsti u } d = \frac{4\pi h_T h_R}{\lambda\Theta_\Delta}$$

$$\Downarrow$$

$$\boxed{d = 449{,}42\,m}$$

(5)

$$\Delta = n \cdot \frac{\lambda}{2} \quad ; \quad \text{1. FRESNELOVA ZONA}$$

$$\Delta = d'' - d' = 1 \cdot \frac{\lambda}{2} = \frac{\lambda}{2}$$

$$\Delta = \sqrt{(h_{Tx} + h_{Rx})^2 + d^2} - \sqrt{(h_{Tx} - h_{Rx})^2 + d^2} = \frac{\lambda}{2}$$

$$(h_{Tx} + h_{Rx})^2 + d^2 = \frac{\lambda^2}{4} + \frac{\lambda}{2}\cdot\sqrt{(h_{Tx} - h_{Rx})^2 + d^2} + (h_{Tx} - h_{Rx})^2 + d^2$$

$$4 h_{Tx} h_{Rx} - \frac{\lambda^2}{4} = \lambda\sqrt{(h_{Tx} - h_{Rx})^2 + d^2} \quad /^2$$

$$16 h_T^2 h_R^2 - 2 h_T h_R \cdot \lambda^2 + \frac{\lambda^4}{16} = \lambda^2\left((h_T - h_R)^2 + d^2\right)$$

$$\boxed{d = \sqrt{\frac{16 h_T^2 h_R^2}{\lambda^2} - (h_T + h_R)^2 + \frac{\lambda^2}{16}}}$$

$$= \frac{2\pi \cdot \nu \cdot \Delta t}{\lambda} \cdot \cos\varphi$$

$$\boxed{f_D = \frac{1}{2\pi} \cdot \frac{\Delta\varphi}{\Delta t} = \frac{\nu}{\lambda} \cdot \cos\varphi}$$

⑥ $f_p = 1850\ MHz$ → (p = POSLANO) $\rightarrow \frac{3 \cdot 10^8}{1850 \cdot 10^6} =$ _____ m

$\nu = 60\ km/h : 3.6\ m/s = 16.67\ m/s$

a) direktno mimo odašiljača

$f = f_p + f_D$ (jer ↑)

$= 1850\ MHz + \frac{\nu}{\lambda} \cos\varphi = 1850\ MHz + 0.000103\ MHz$

$= 1850.000103\ MHz$

→ jer ide dirto na odašiljač, kut = 0°

f je veća kod se približava

b) direktno od odašiljača

$f = f_p + f_D = 1850 + \frac{\nu}{\lambda} \cos\varphi = 1848.999897\ MHz$

(180° ↑, $\cos\varphi$ = −1)

f je manja kod se udaljava

c) OKOMITO NA ODAŠILJAČ

$f = f_p + f_D = 1850 + \frac{\nu}{\lambda} \cos\varphi = 1850\ MHz$

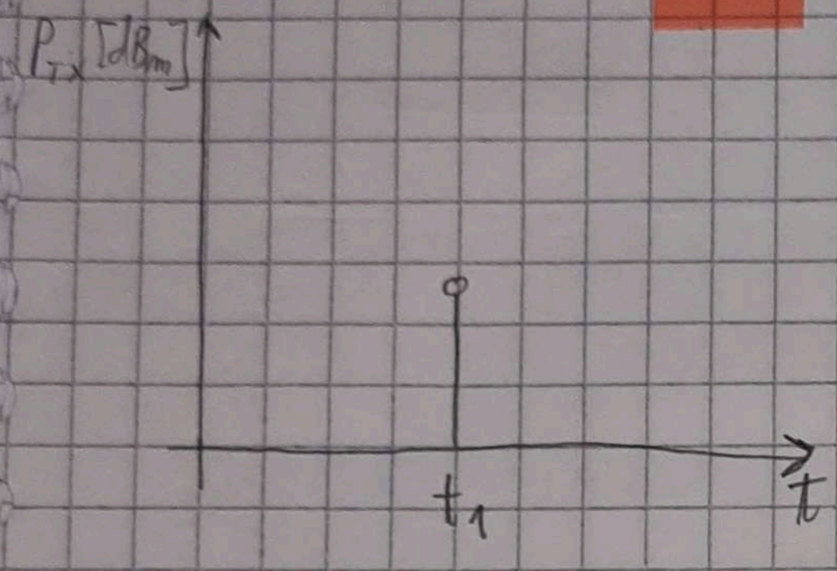
($\cos\varphi = 0$, 90° ↑)

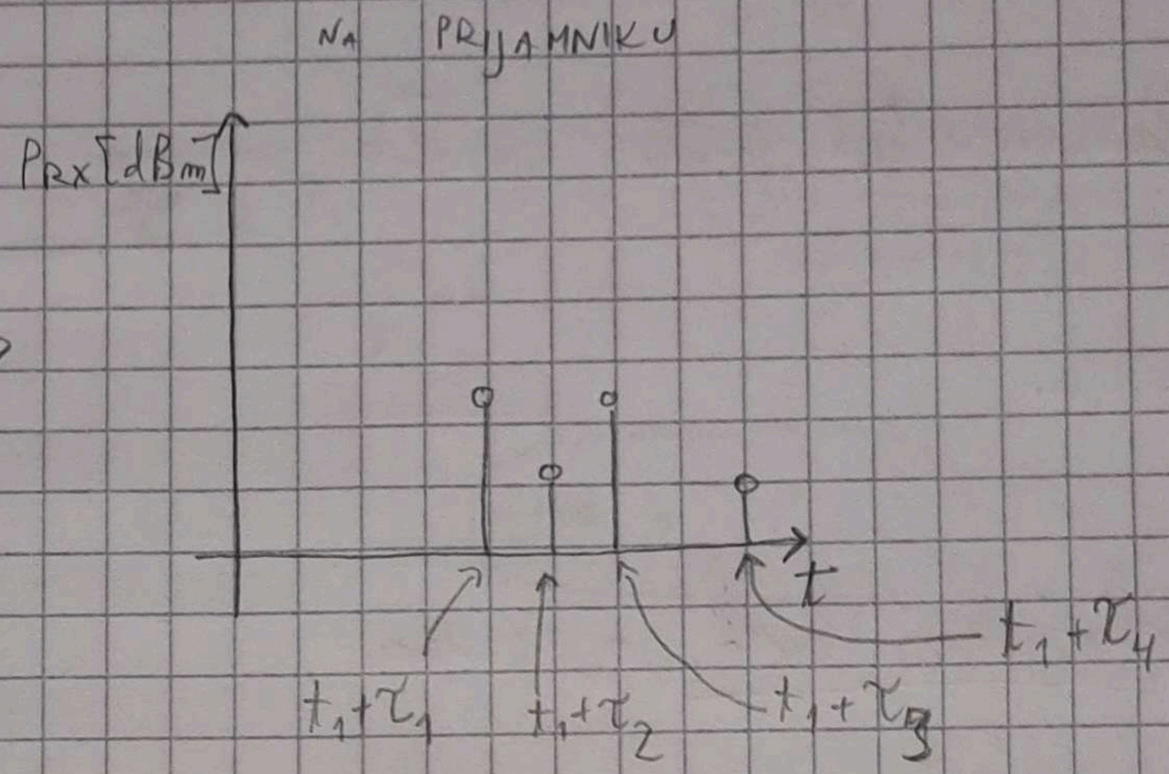
f je ista kod se kreće okomito

12.4.2024.

6. tjedan, part II

PDP - POWER DELAY PROFILE

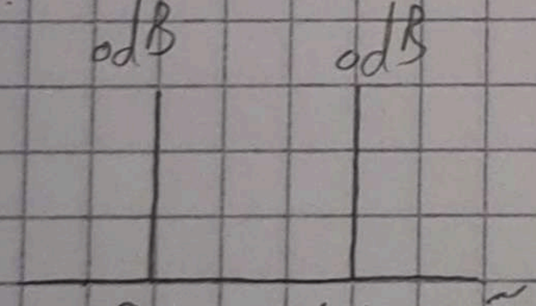




$\overline{\tau}$ - SREDNJE KAŠNJENJE

$\overline{\tau}_{RMS}$ - SREDNJE RASIPANJE KAŠNJENJA/DISPERZIJA

①



$0\,dB = 1$

$$\overline{\tau} = \frac{\sum a_k^2 \tau}{\sum a_k^2} = \frac{\sum_k \mu_k \tau_k}{\sum_k \mu_k}$$

APSOLUTNI IZNOSI

$\sum_k a_k$ → AMPLITUDA

$\sum_k \mu_k$ → SNAGA

→ moraš pretvoriti dB u obs. veličine

$$\rightarrow = \frac{1 \cdot 0 + 1 \cdot 1\,\mu s}{1+1} = 0.5\,\mu s$$

$$\overline{\tau}_{RMS} = \sqrt{\overline{\tau^2} - (\overline{\tau})^2} = \sqrt{0.5\,\mu s^2 - 0.5^2\,\mu s^2} = 0.5\,\mu s$$

$$\rightarrow \overline{\tau^2} = \frac{\sum_k \mu_k \tau_k^2}{\sum_k \mu_k} = \frac{1 \cdot 0 + 1 \cdot (1\,\mu s)^2}{1+1} = 0.5\,\mu s$$

KOHERENCIJSKI POJAS -> B_c

->mjera raspona f u kojoj kanal propušta f (tak reš) jednako

->kanal. kanala se u tom pojasu smatra ravnom

->

τ_{RMS}

->ovisi o korelacijskom koef. dvojnika

if: $\varrho = 0,9$ $\longrightarrow$ $B_c \approx \frac{1}{6\pi \tau_{RMS}}$

if: $\varrho = 0,5$ $\longrightarrow$ $B_c \approx \frac{1}{2\pi \tau_{RMS}}$

KOHERENCIJSKO VRIJEME -> min. trajanje signala da bismo primjetili

frekv. disperziju

-> $T_c \approx \frac{1}{f_0}$, $T_c \approx \frac{9}{16\pi f_0}$

->DOPPLER

->prema tome određuje kakav je fading

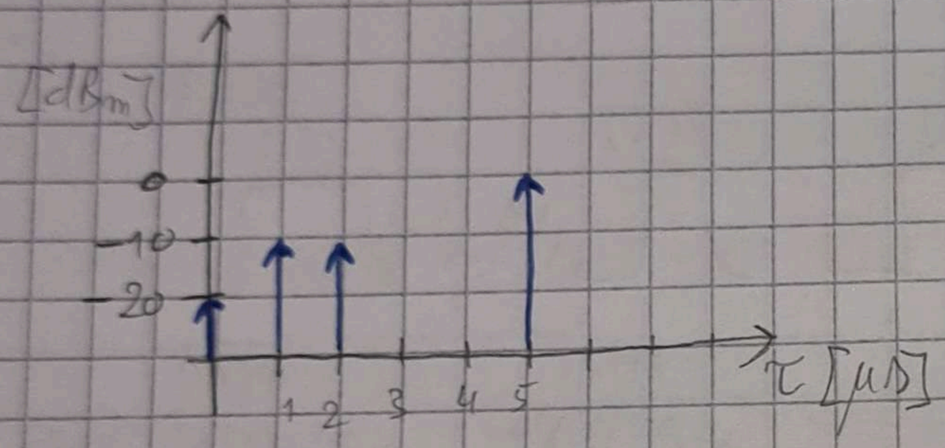
POP

0dB = 1, -10dB = 0.1, -20dB = 0.01

② $\overline{\tau}$ i $\overline{\tau}_{RMS}$ = ?

↳ KOREL. KOEF.

$\vartheta = 0.5 \rightarrow B_c = ?$



$$\overline{\tau} = \frac{\sum_k p_k \cdot \tau_k}{\sum_k p_k} = \frac{0.01 \cdot 0\mu s + 0.1 \cdot 1 + 0.1 \cdot 2 + 1 \cdot 5\mu s}{0.01 + 0.1 + 0.1 + 1}$$

$$\overline{\tau} = 4.38\,\mu s$$

$$\overline{\tau}_{RMS} = \sqrt{\overline{\tau^2} - (\overline{\tau})^2} = \sqrt{21.07\,\mu s^2 - (4.38\,\mu s)^2} = 1.37\,\mu s$$

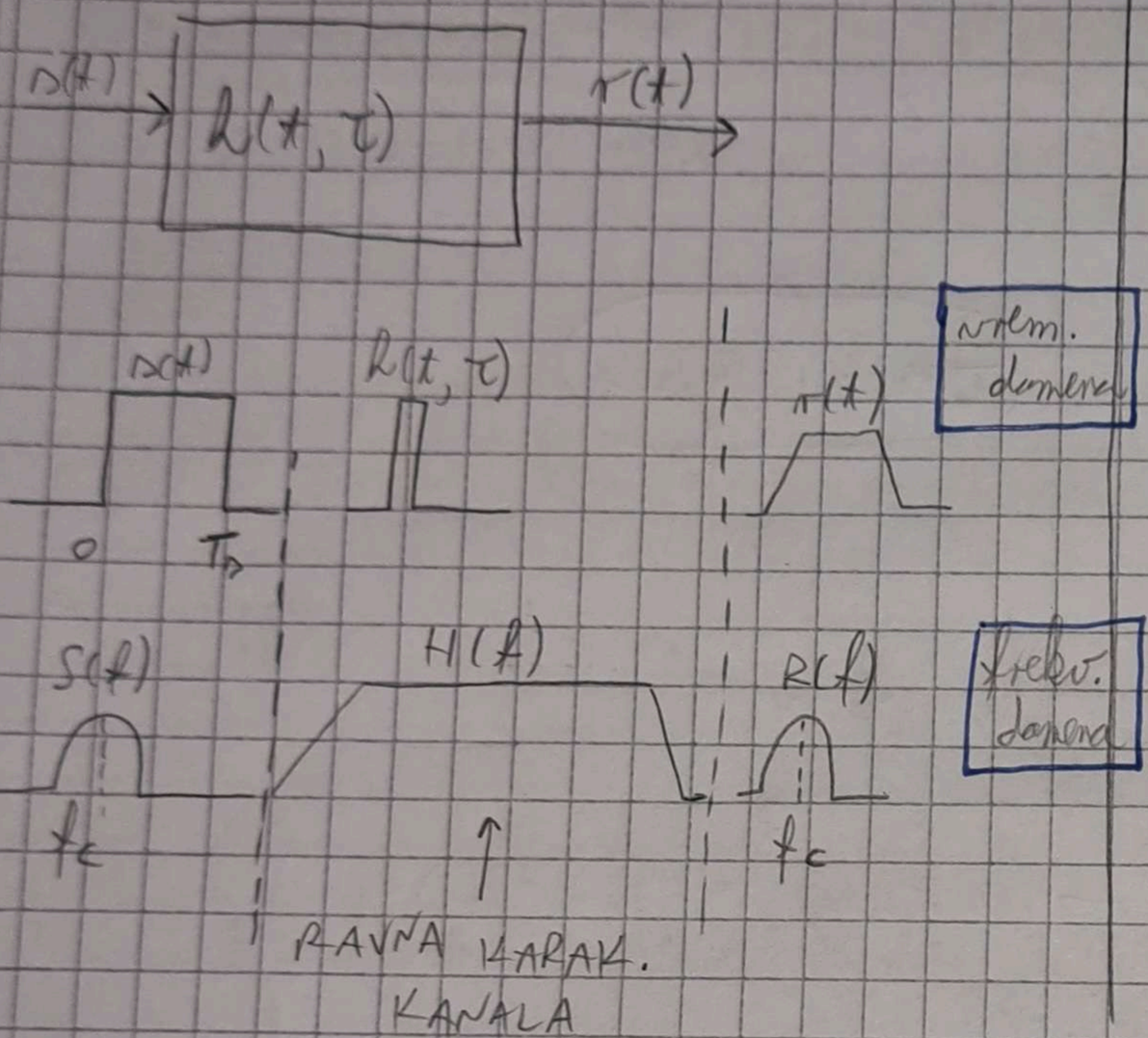
$$\rightarrow \overline{\tau^2} = \frac{\sum_k p_k \cdot \tau_k^2}{\sum_k p_k} = \frac{0.01 \cdot 0^2 + 0.1 \cdot 1^2 + 0.1 \cdot 2^2 + 1 \cdot 5^2}{0.01 + 0.1 + 1}$$

$$= 21.07\,\mu s^2$$

$$\vartheta = 0.5 \rightarrow B_c \approx \frac{1}{2\pi \overline{\tau}_{RMS}} = 116\,kHz$$

③

RAVNI FEDING



KAD JE U frekv. domeni ŠIROKO JE U vrem. domeni USKO

$$B_c >> B, \quad T_{RMS} << T_s$$

BRZI FEDING

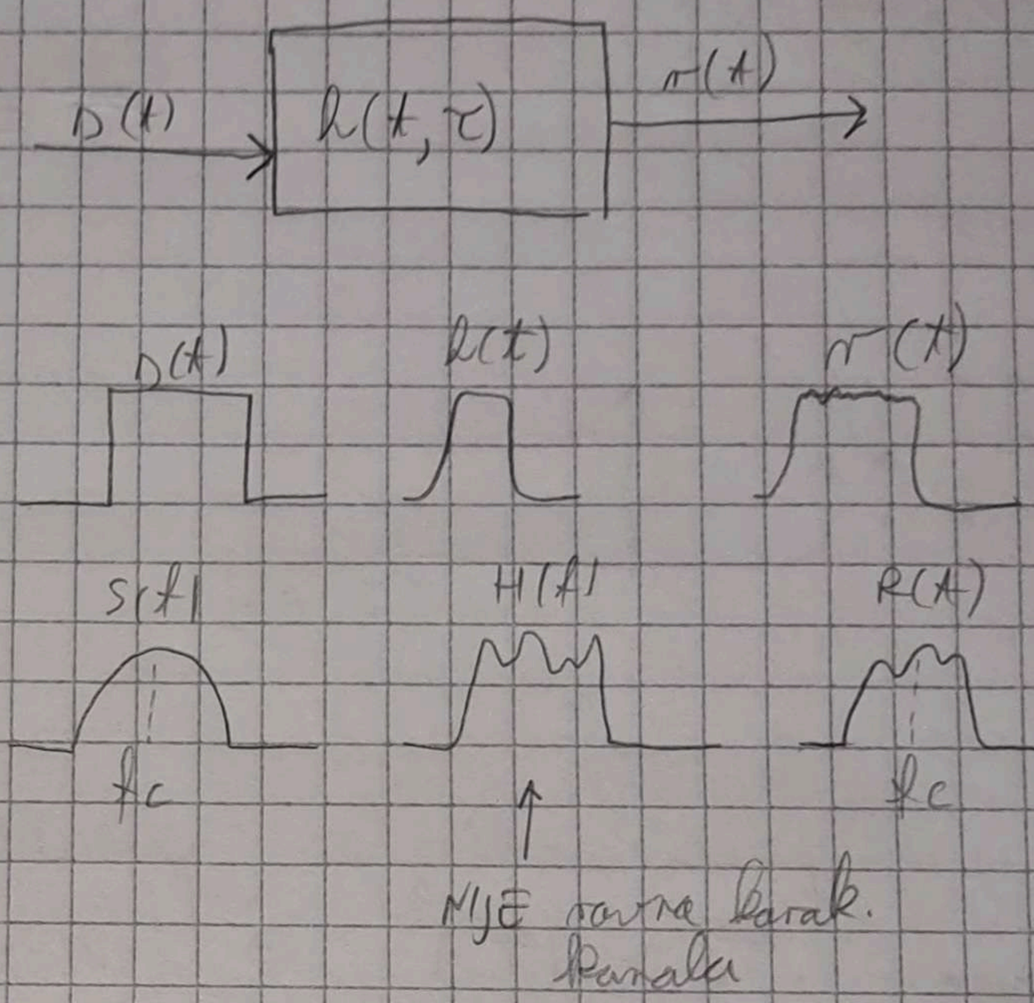
$T_s > T_c$

$B < B_D$

↳ $B_D = [-f_D, f_D]$

↳ DOPPLEROVA ŠIRINA POJASA

FREKVENCIJSKI SELEKTIVNI FEDING



$$B_c < B \; ; \quad T_{RMS} > T_s$$

SPORI FEDING

$T_s << T_c$

$B >> B_D$

④ BPSK

$R_B = 100\ kbit/s$

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a) $\Rightarrow \tau_{RMS} = ?$ → ravni feding → mojet → $\underline{T_s \geq 10\,\tau_{RMS}}$

$R_B = R_S \cdot \log_2(M) = R_S \cdot \log_2(2)$

↓

BRZINA PRIJENOSA SIMBOLA

$T_B = \frac{1}{R_B} = \frac{T_S}{\log_2(M)} = \frac{T_S}{\log_2 2}$

↑

TRAJANJE BITA

$T_S = T_b = \frac{1}{R_b} = \underline{10^{-5}\ s}$

$\tau_{RMS} \leq \frac{T_s}{10} \rightarrow \underline{[0,\ 10^{-6}]\ s}$

c) SPORI ILI brzi feding?

$T_s = 10^{-5}\ s$, $T_c = 10^{-3}\ s$

↓ ↓

SPORI FEDING

jer $\underline{T_s << T_c}$

b) $f = 2\,GHz$

$v = 50\ km/h$

$T_c = ?$

$T_c \approx \frac{1}{f_D} = \frac{1}{\frac{v}{\lambda}\cos\theta} = \underline{3.72\ ms}$ ← OVISNO O APROKSIMACIJI, oba SU TOČNA ODG.

$\cos\theta \approx 1$

141 $T_c \approx \frac{9}{16\pi f_D} = \underline{1.93\ ms}$ ↑

18.4.2024.

7. tjedan

PDP nastavak

DIRACOVA FUNKCIJA

① a)

$$P(\tau) = \sum_{m=0}^{2} \frac{10^{-6}}{m^2+1} \delta(\tau - m \cdot 10^{-6}) \rightarrow \text{IZRAZ ZA PDP}$$

↳ SVUGDJE JE 0 OSIM $\delta(x)$, $x=0$ — U NULI

NAMJEŠTAMO τ ↘

(I) $\tau = 0 \rightarrow P(0) = \frac{10^{-6}}{0+1}\delta(0-0) + \frac{10^{-6}}{1^2+1}\delta(0+10^{-6}) + \frac{10^{-6}}{2^2+1}\delta(0-2\cdot 10^{-6})$

JEDINI PREŽIVI

$= 10^{-6}\,W = -60\,dBW = -30\,dBm$ → za PDP

(II) $\tau = 10^{-6} \rightarrow P(10^{-6}) = \frac{10^{-6}}{0+1}\delta(10^{-6}-0) + \frac{10^{-6}}{1^2+1}\delta(10^{-6}-10^{-6}) + \frac{10^{-6}}{2^2+1}\delta(10^{-6}-2\cdot 10^{-6})$

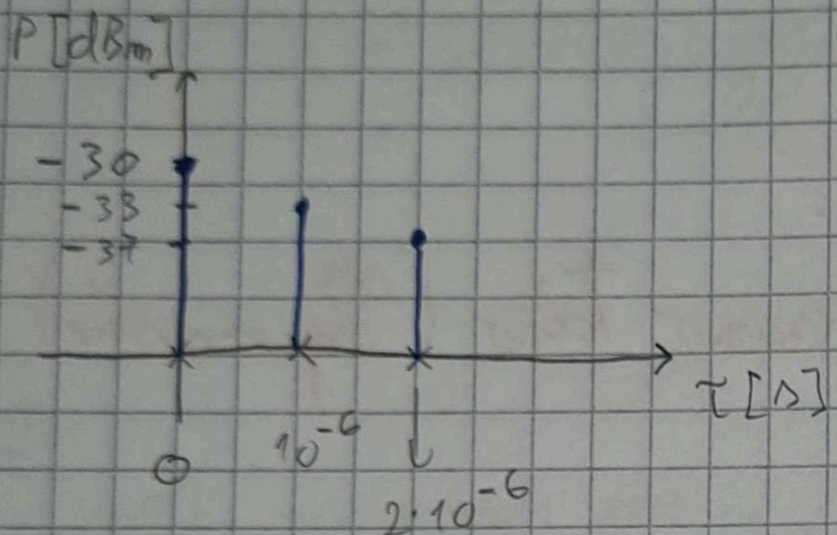
JEDINI PREŽIVI

$= 5 \cdot 10^{-7}\,W = -63\,dBW = -33\,dBm$

(III) $\tau = 2 \cdot 10^{-6}$

$$P(\tau) = \frac{10^{-6}}{0+1} \delta(2 \cdot 10^{-6} - 0) + \frac{10^{-6}}{1+1} \delta(2 \cdot 10^{-6} - 10^{-6}) + \underbrace{\frac{10^{-6}}{2^2+1} \delta(2 \cdot 10^{-6} - 2 \cdot 10^{-6})}_{\text{JEDINI PREŽIVI}}$$

$$= 2 \cdot 10^{-7} = -67 \text{ dBW} = \underline{\underline{-37 \text{ dBm}}}$$



b) srednja snaga =? $\rightarrow$ $P_{avg} = \frac{1}{3} \sum_{i=0}^{2} P(n) = \frac{1}{3} \cdot \left[10^{-6} + 5 \cdot 10^{-7} + 2 \cdot 10^{-7} \right] W$

$= 5.67 \cdot 10^{-7} W = -62.46 \text{ dBW}$

$= \underline{-32.46 \text{ dBm}}$

c) SREDNJE RASIPANJE KAŠNJENJA

$$\tau_{RMS} = \sqrt{\overline{\tau^2} - (\overline{\tau})^2} = 0.696 \, \mu s$$

$$\hookrightarrow \overline{\tau} = \frac{\sum p_k \cdot \tau_k}{\sum p_k} = \frac{10^{-6} \cdot 0 + 5 \cdot 10^{-7} \cdot 10^{-6} + 2 \cdot 10^{-7} \cdot 2 \cdot 10^{-6}}{10^{-6} + 5 \cdot 10^{-7} + 2 \cdot 10^{-7}} = \underline{5.3 \cdot 10^{-7} s}$$

UZIMA APSOLUTNE VRIJ. !!!

$$\hookrightarrow \overline{\tau^2} = \frac{\sum p_k \cdot \tau_k^2}{\sum p_k} = \frac{10^{-6} \cdot 0^2 + 5 \cdot 10^{-7} \cdot (10^{-6})^2 + 2 \cdot 10^{-7} \cdot (2 \cdot 10^{-6})^2}{10^{-6} + 5 \cdot 10^{-7} + 2 \cdot 10^{-7}} = \underline{7.65 \cdot 10^{-13} s^2}$$

$1.7 \cdot 10^{-6}$

d) AKO IMAMO 256-QAM modulaciju:

$2\,Mbit/s = R_b$

256 SIMBOLA → SVAKI SIMBOL IMA 8 BITOVA

$\log_2 M \cdot R_s = R_b = 8 \cdot R_s$

gledamo trajanje simbola

$T_s = \frac{1}{R_s} = 4\,\mu s$

i $\tau_{RMS} = 0.7\,\mu s$

i trebamo sel. FEDING ILI RAVNI FEDING? → ne znamo točno (na sigurnošću)

$T_s < \tau_{RMS}$

$T_s \geq 10 \cdot \tau_{RMS}$

(i znaj za brzi/spori feding uvjet!)

e) ŠIRINA POJASA da KANAL IMA KONST. pojačanje?

↳ VRIJEDI ZA KOHERENCIJSKI POJAS (ρ mije zadan pa računaj za oboje)

$\rho = 0.5$

$B_c \approx \frac{1}{2\pi\tau_{RMS}} = 227.3\,kHz$

$\rho = 0.9 \rightarrow B_c \approx \frac{1}{6\pi\tau_{RMS}} = 75.79\,kHz$

DIVERZITI

↳ ISTI SIGNAL SE ŠALJE NEKORELIRANIM KANALIMA

→ podjela: • MAKRODIVERZITI / MIKRODIVERZITI

• SELEKCIJSKI / KOMBINACIJSKI

②

90% vremena ~~nam~~ je P na Rx $\underset{\sim}{1mW} = 10 \cdot 10^{-10}$, a ostatak vremena $\underline{0}$

BER = 90% vremena 10^{-10}, ostatak vremena 0.5

PROSJEČNI BER_{avg} =? AKO IMAMO 1, 2, 3 antene

$BER_{avg} = 0.9 \cdot 10^{-10} + 0.1 \cdot 0.5 = \underline{0.05} = BER_{avg}$ → 1 antena

2 antene

DA NA OBJE IMAMO SIGNAL $= 0.9 \cdot 0.9 = 0.81$

DA NA OBJE NEMA SIGNAL $= 0.1 \cdot 0.1 = 0.01$

DA 1 ima A DRUGA nema $= 0.9 \cdot 0.1 = 0.09$ · 2

$\Sigma = 1$ ✓

1 ✓ 2 ✗

ili

1 ✗ 2 ✓

SIGNAL barem na 1

$BER_{avg} = 0.99 \cdot 10^{-10} + 0.01 \cdot 0.5$

$= \underline{0.005}$ → 2 antene

3 antene

$BER_{avg} = 0.999 \cdot 10^{-10} + 0.001 \cdot 0.5 = \underline{0,0005}$ za 3 antene

DIVERZITI je dobar KAD IMAŠ VIŠE antena (vidiš po prinjeru kako BER pada s brojem antena)

③ RAYLEIGH DISTRIB. ; DIVERZITI S 4 grane

PROSJEČNI SNR = 20 dB ; % da će SNR past ispod 10 = ?

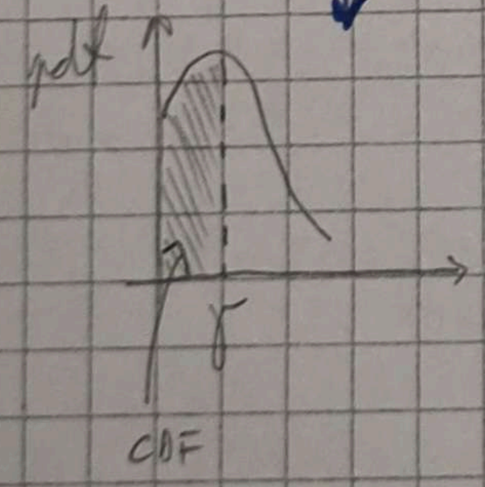
$= \Gamma = \bar{\gamma}$; % ispoda ↓ ; γ_m ↓

→ za small scale feding je log norm razdioba

→ PONOVI/NAUČI NZ predavanja

Znaj GUSTOĆU RAY. DISTRIB i CDF →

PDF ↓ ; Lykomol. DISTRIB FUNKCIJA



$cdf = \int_0^{\gamma} pdf$

$pdf\ f(\bar{\gamma}_0) = \frac{1}{\bar{\gamma}_0} \exp\left(-\frac{\gamma_m}{\bar{\gamma}}\right)$

znaj ove formule

$cdf\ (\bar{\gamma}_m) = 1 - \exp\left(-\frac{\gamma_m}{\bar{\gamma}}\right)$

↳ % ISPADA (po def.)

$cdf\ (\bar{\gamma}_m^N) = \left(1 - \exp\left(-\frac{\gamma_m}{\bar{\gamma}}\right)\right)^N$

APS. IZNOS! → 10 dB = 10
20 dB = 100
↓
10/100

$$P(10dB) = 1 - \exp(-0.1)$$

$$= \underline{0.095}$$

$$P(10dB) \rightarrow \left[1 - \exp(-0.1)\right]^4 = 0.0000082$$

↑ DIVERZITI (nr. grana)

→ % ispada ako ima 4 grane