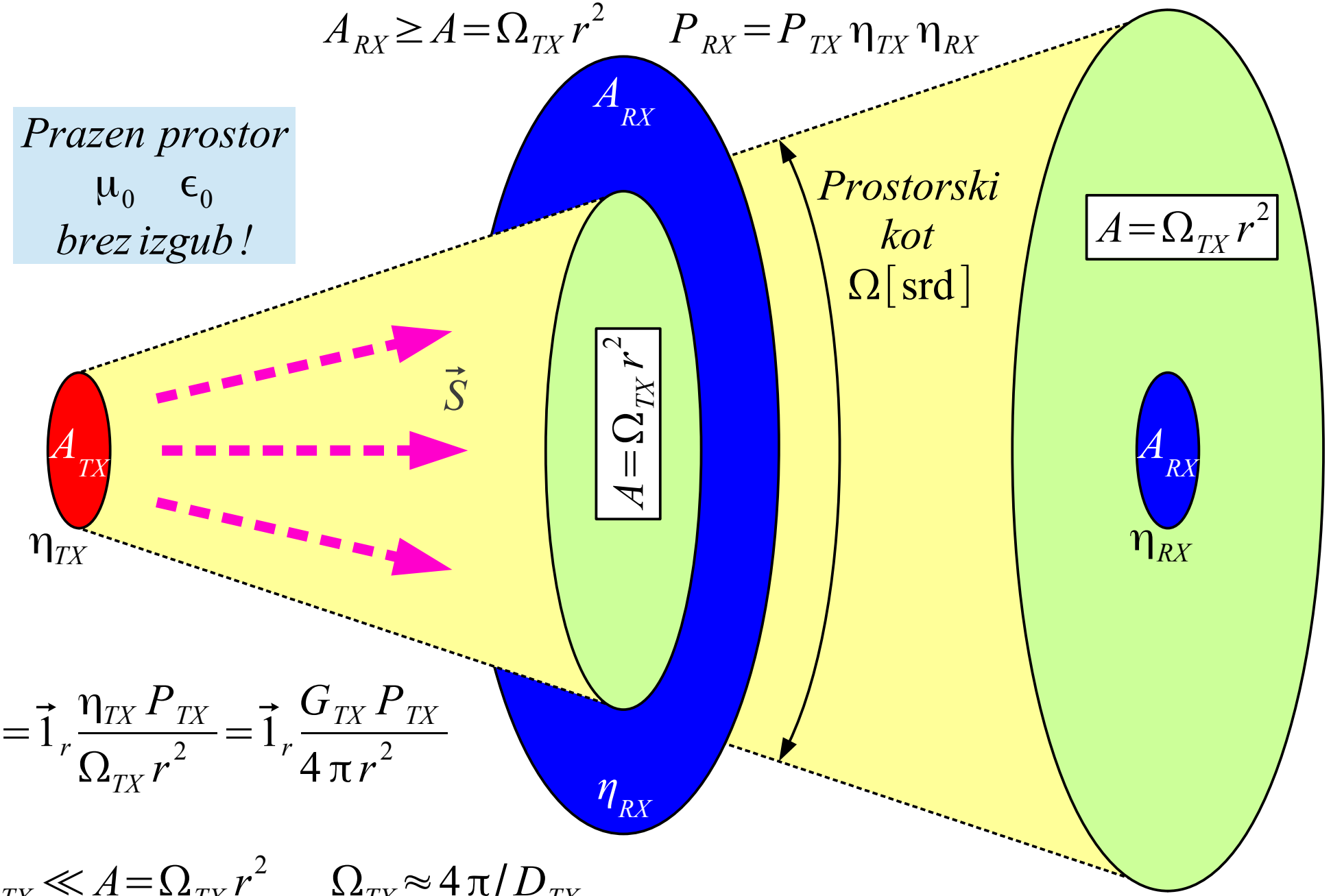
Meritve

Vesoljska elektrarna (rectenna)

$A_{RX} \geq A = \Omega_{TX} r^2$ $\quad P_{RX} = P_{TX}\,\eta_{TX}\,\eta_{RX}$



$$\vec{S} = \vec{1}_r \frac{\eta_{TX} P_{TX}}{\Omega_{TX} r^2} = \vec{1}_r \frac{G_{TX} P_{TX}}{4\pi r^2}$$

$A_{TX} \ll A = \Omega_{TX} r^2$ $\quad \Omega_{TX} \approx 4\pi / D_{TX}$

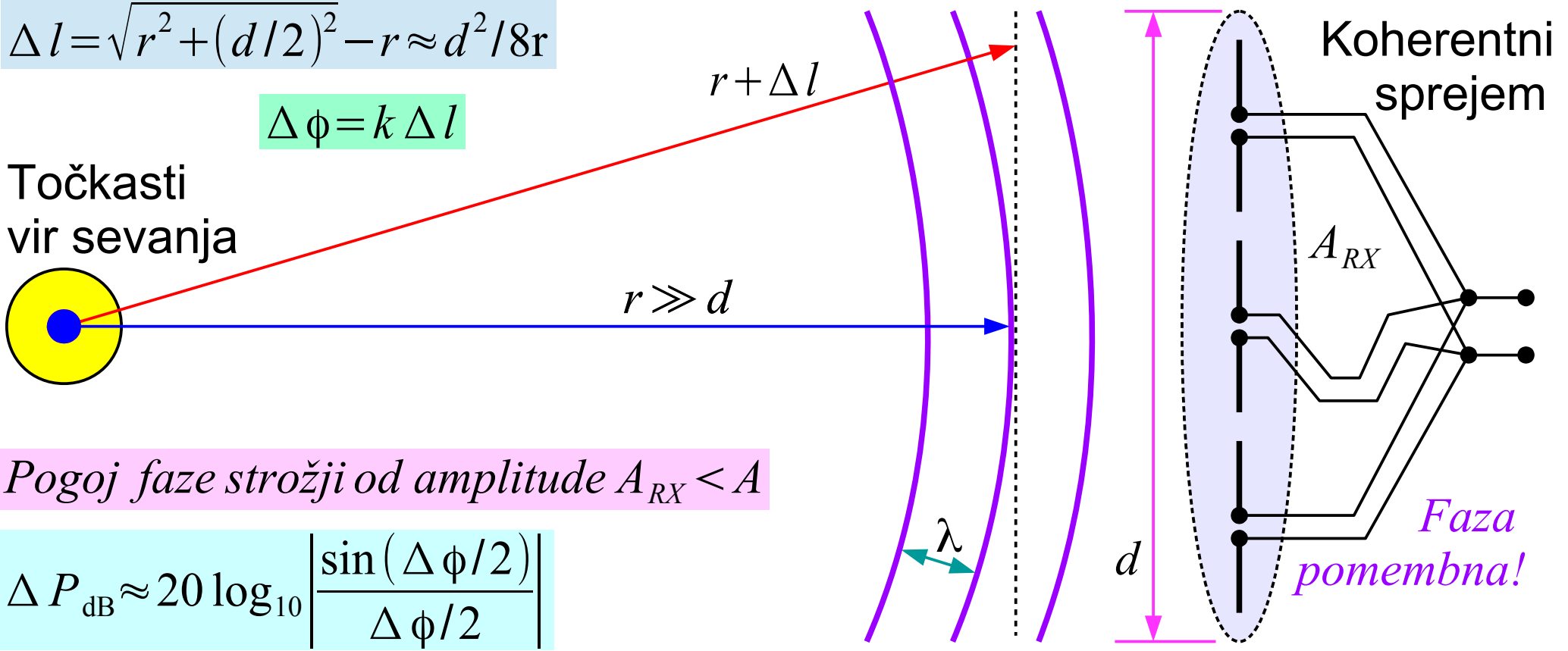
Brezvrvična zveza $\quad P_{RX} \ll P_{TX}$

$P_{RX} = |\vec{S}|\, A_{effRX}\, \eta_{RX}$ $\quad A_{RX} \ll A = \Omega_{TX} r^2$

<u>Zahteve za površine anten</u>

$$\Delta l = \sqrt{r^2 + (d/2)^2} - r \approx d^2/8r$$

$$\Delta\phi = k\,\Delta l$$

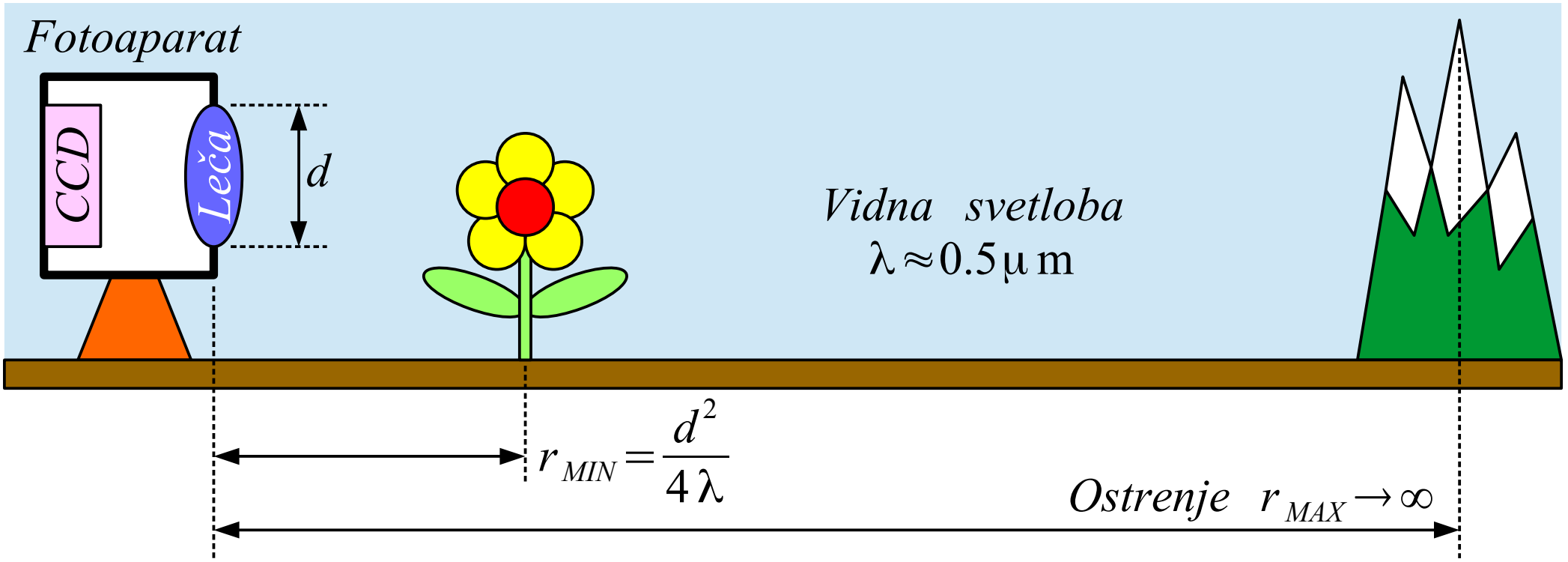


Pogoj faze strožji od amplitude $A_{RX} < A$

$$\Delta P_{\mathrm{dB}} \approx 20 \log_{10} \left| \frac{\sin(\Delta\phi/2)}{\Delta\phi/2} \right|$$

Δl	$\Delta\phi$[rd]	ΔP[dB]	$r \geq$	Uporaba
λ/2	π	−3.922	$d^2/4\lambda$	Globinska ostrina fotoaparata
λ/4	π/2	−0.912	$d^2/2\lambda$	Lord Rayleigh 1891
λ/8	π/4	−0.224	d^2/λ	
λ/16	π/8	−0.056	$2d^2/\lambda$	Meritev radijskih signalov

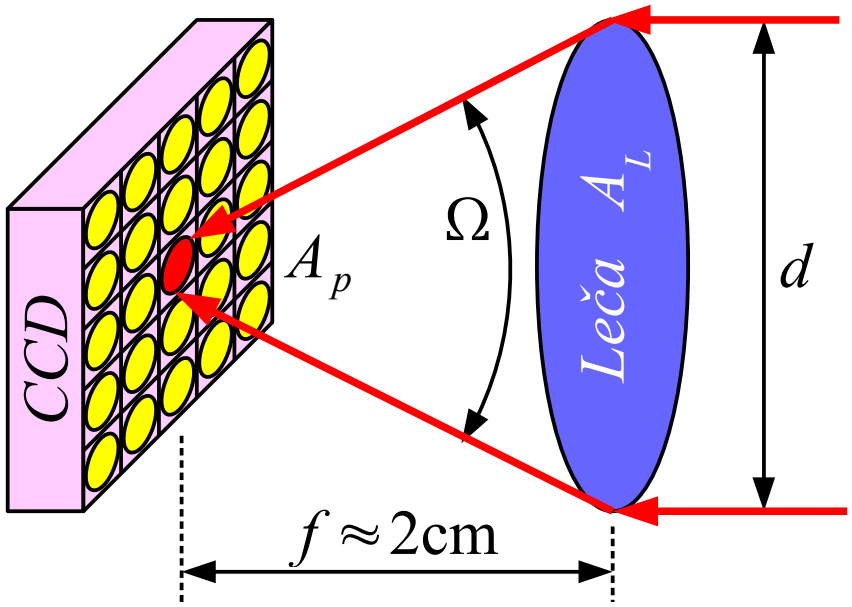
Fraunhoferjev pogoj (Rayleighjeva razdalja)



$$\Omega \approx \frac{\lambda^2}{A_p} = \frac{\lambda^2}{\pi (d_p/2)^2}$$

$$A_L = \pi (d/2)^2 \approx \Omega f^2$$

$$d_p \approx \frac{4\lambda f}{\pi d}$$



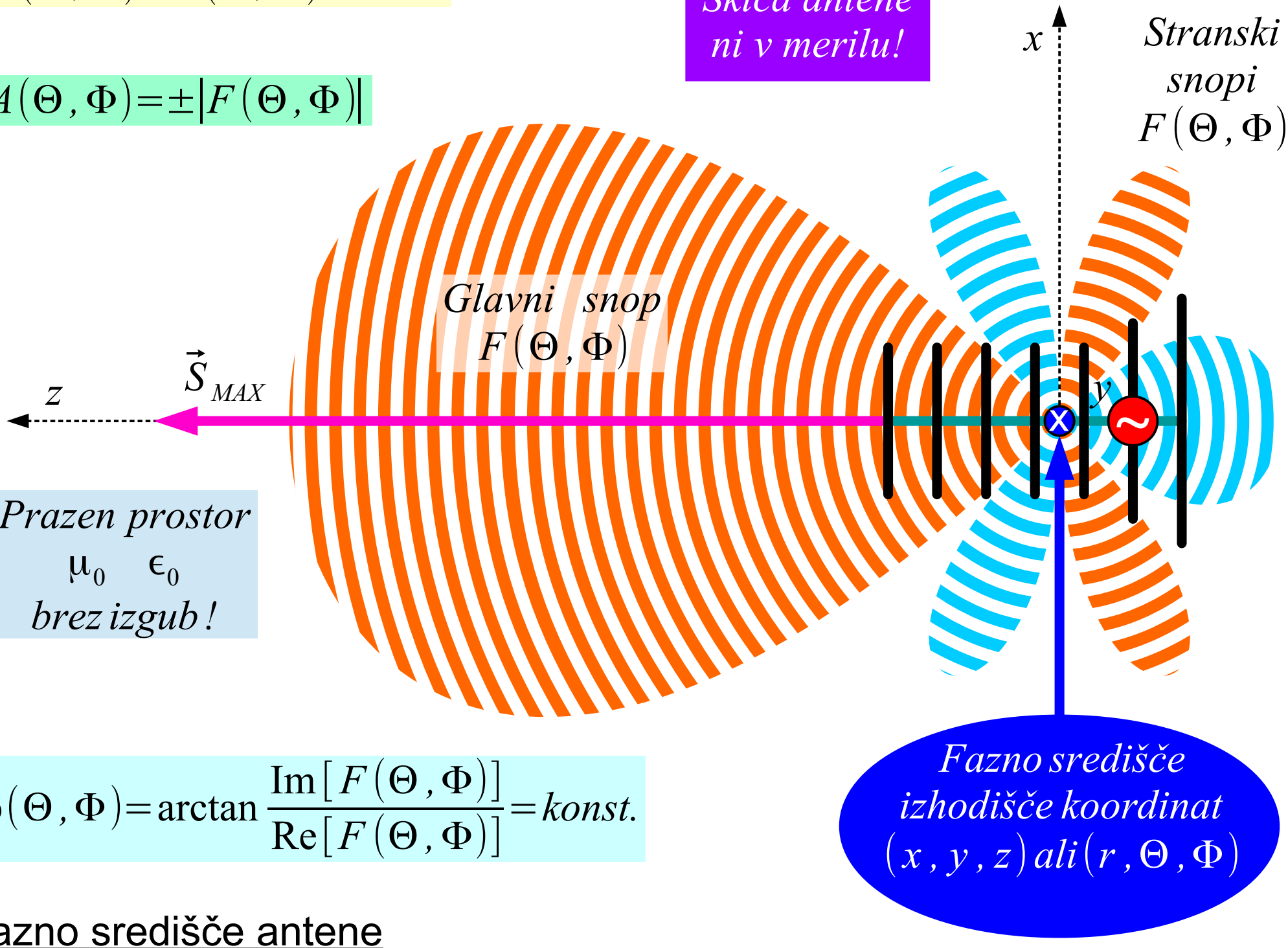
Premer d	Razdalja r_{MIN}	Odprtina f/d	Ločljivost d_p
1cm	50m	2:1	1.3μm
1mm	0.5m	20:1	13μm

Globinska ostrina fotoaparata

$$F(\Theta,\Phi)=A(\Theta,\Phi)\,e^{j\phi(\Theta,\Phi)}$$

$$A(\Theta,\Phi)=\pm\left|F(\Theta,\Phi)\right|$$

Skica antene ni v merilu!



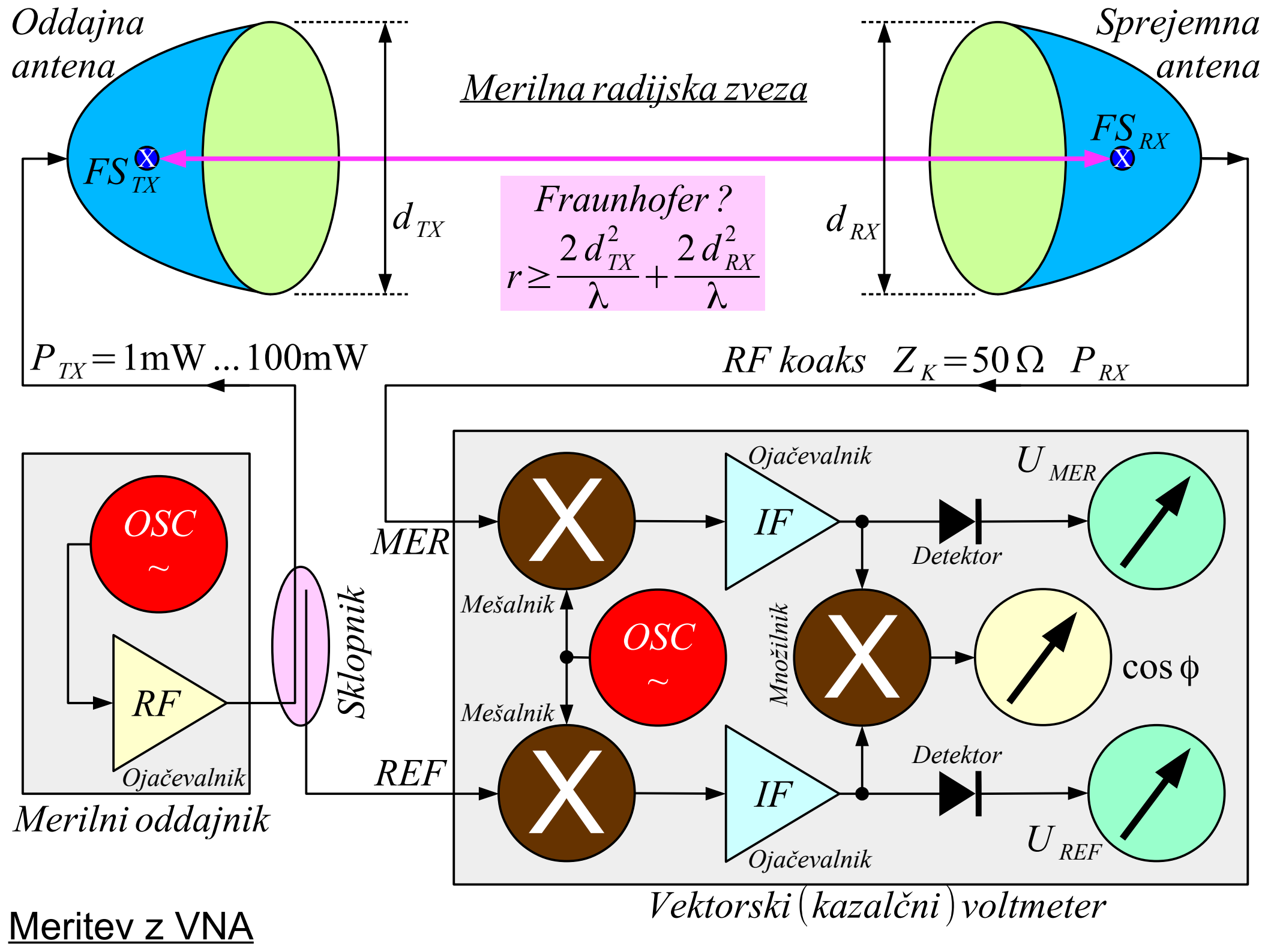
Prazen prostor

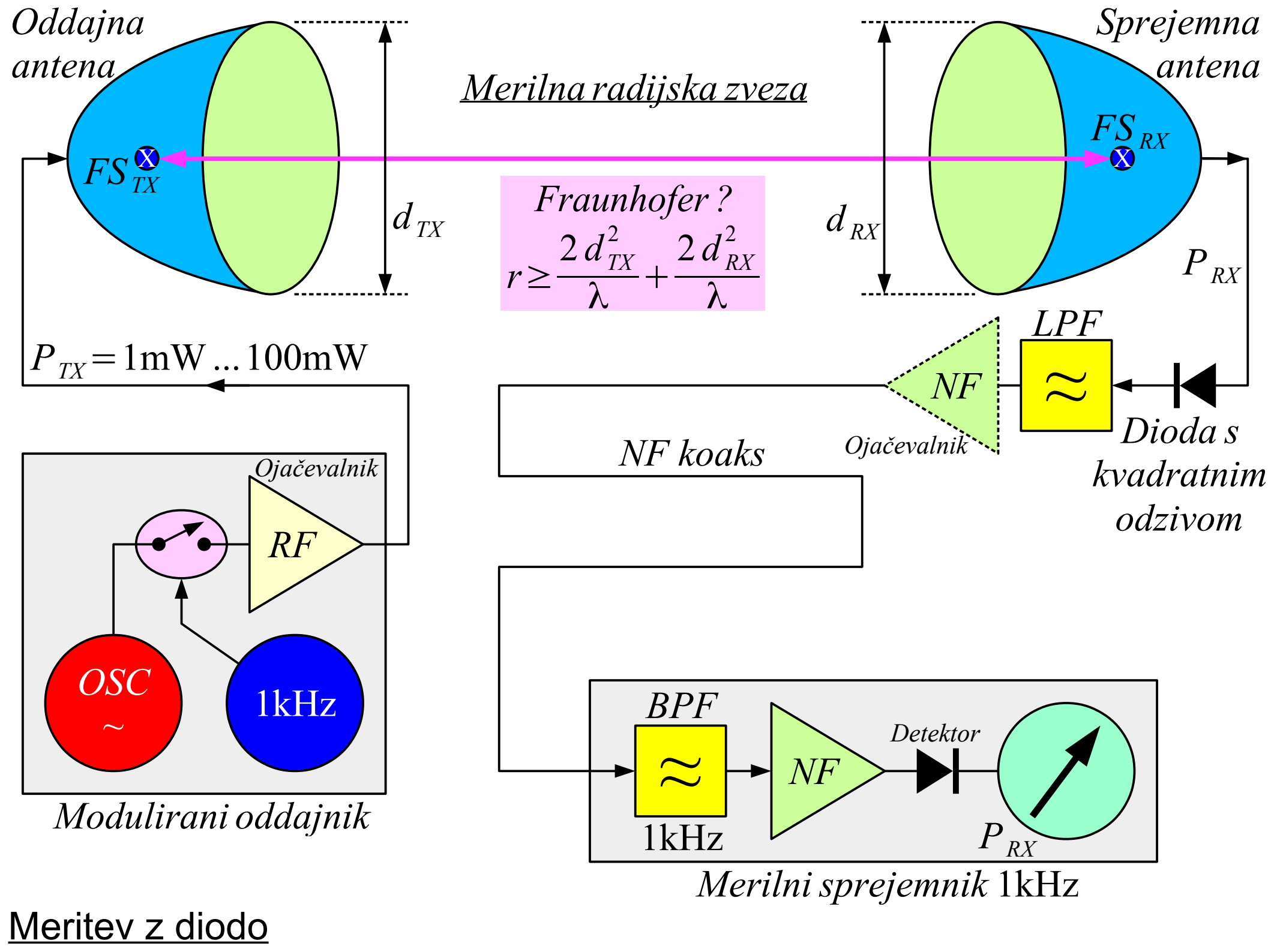
$\mu_0 \quad \epsilon_0$

brez izgub!

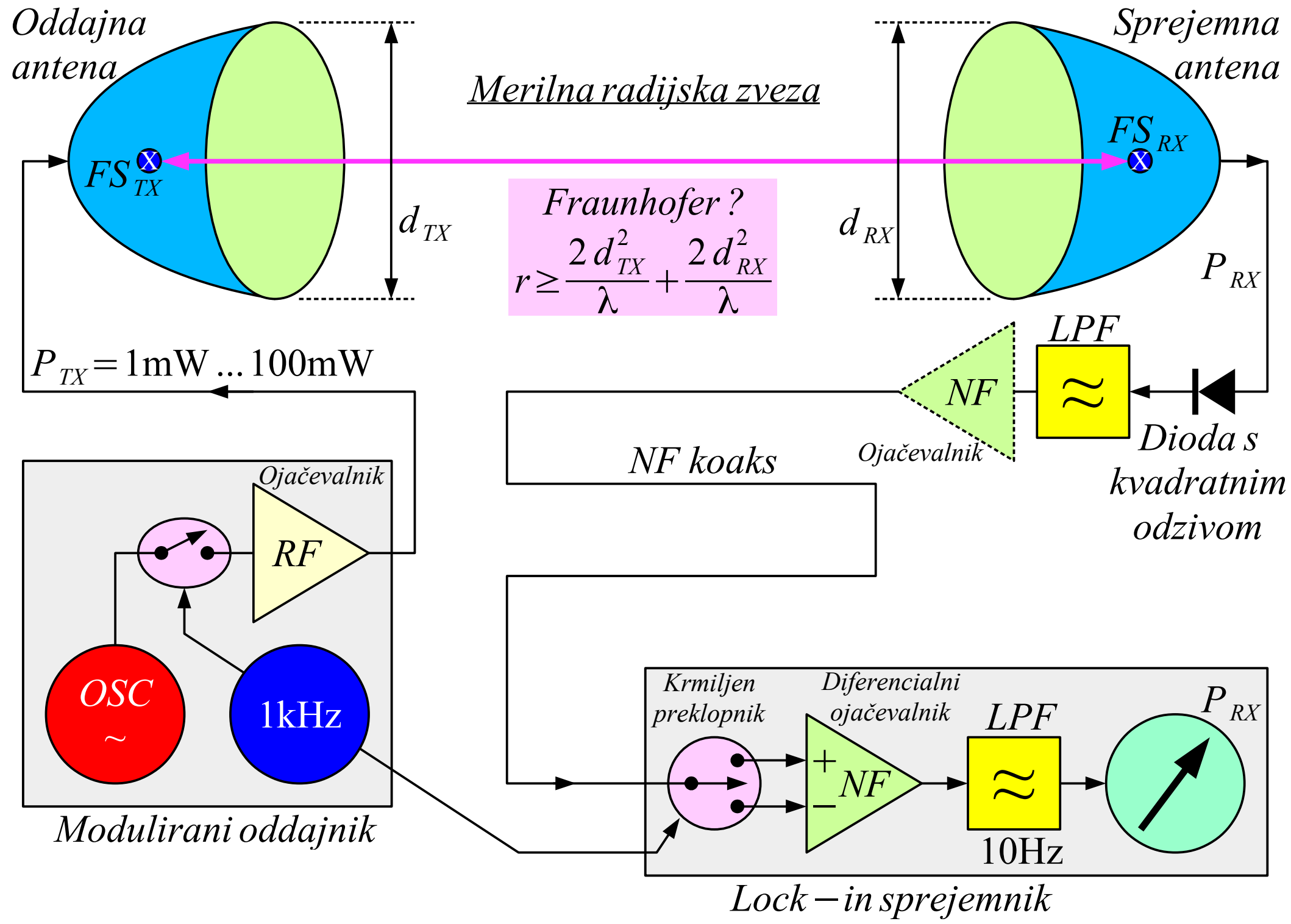
$$\phi(\Theta,\Phi)=\arctan\frac{\mathrm{Im}\left[F(\Theta,\Phi)\right]}{\mathrm{Re}\left[F(\Theta,\Phi)\right]}=konst.$$

Fazno središče antene


Oddajna antena
Merilna radijska zveza
Sprejemna antena
FS TX
FS RX
d TX
d RX
Fraunhofer ?
r ≥ 2 d²TX / λ + 2 d²RX / λ
P TX = 1mW ... 100mW
RF koaks Z K = 50 Ω P RX
OSC
~
RF
Ojačevalnik
Merilni oddajnik
Sklopnik
MER
REF
Mešalnik
Mešalnik
OSC
~
Ojačevalnik
IF
Detektor
U MER
Množilnik
cos ϕ
Detektor
IF
Ojačevalnik
U REF
Vektorski (kazalčni) voltmeter
Meritev z VNA



Meritev z diodo



Meritev z lock-in

$$D=\frac{4\pi\left|F\left(\Theta_{MAX},\Phi_{MAX}\right)\right|^2}{\oiint\limits_{4\pi}\left|F\left(\Theta,\Phi\right)\right|^2 d\,\Omega}=\frac{4\pi\left|F\left(\Theta_{MAX},\Phi_{MAX}\right)\right|^2}{\int\limits_0^{\pi}\int\limits_0^{2\pi}\left|F\left(\Theta,\Phi\right)\right|^2\sin\Theta\,d\,\Theta\,d\,\Phi}$$

$$0\le\Theta\le\pi\qquad\Phi_{1,}\,0\le\Phi_{2,}\,\Phi_3\ldots\Phi_N\le 2\pi\;\rightarrow\;\oiint\limits_{4\pi}\left|F\left(\Theta,\Phi\right)\right|^2 d\,\Omega\approx$$

$$\approx\frac{2\pi}{N}\int\limits_0^{\pi}\left[\left|F\left(\Theta,\Phi_1\right)\right|^2+\left|F\left(\Theta,\Phi_2\right)\right|^2+\left|F\left(\Theta,\Phi_3\right)\right|^2+\ldots+\left|F\left(\Theta,\Phi_N\right)\right|^2\right]\sin\Theta\,d\,\Theta$$

$$-\pi\le\Theta\le\pi\qquad\Phi_{1,}\,0\le\Phi_{2,}\,\Phi_3\ldots\Phi_N\le\pi\;\rightarrow\;\oiint\limits_{4\pi}\left|F\left(\Theta,\Phi\right)\right|^2 d\,\Omega\approx$$

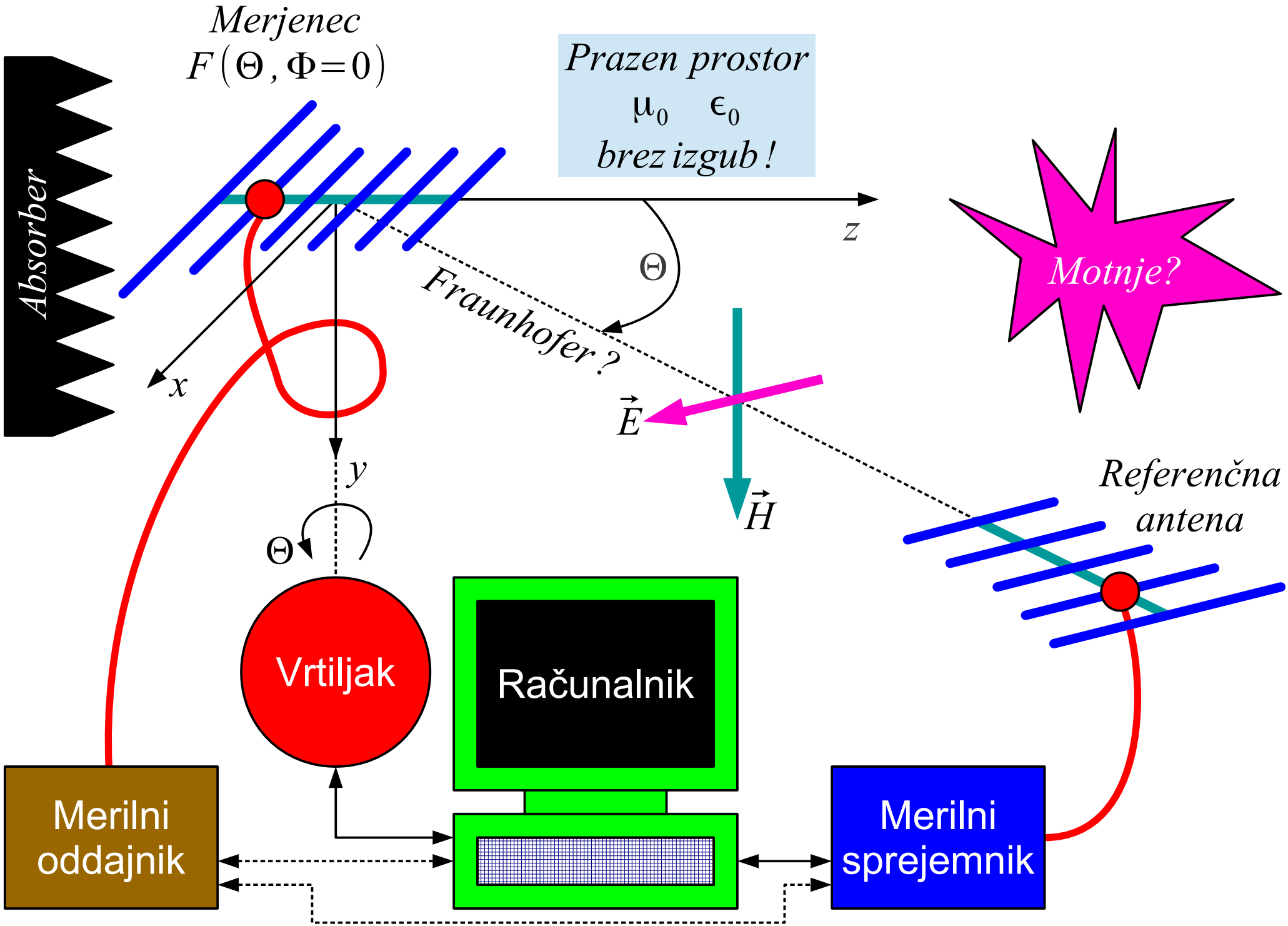
$$\approx\frac{\pi}{N}\int\limits_{-\pi}^{\pi}\left[\left|F\left(\Theta,\Phi_1\right)\right|^2+\left|F\left(\Theta,\Phi_2\right)\right|^2+\left|F\left(\Theta,\Phi_3\right)\right|^2+\ldots+\left|F\left(\Theta,\Phi_N\right)\right|^2\right]\sin|\Theta|\,d\,\Theta$$

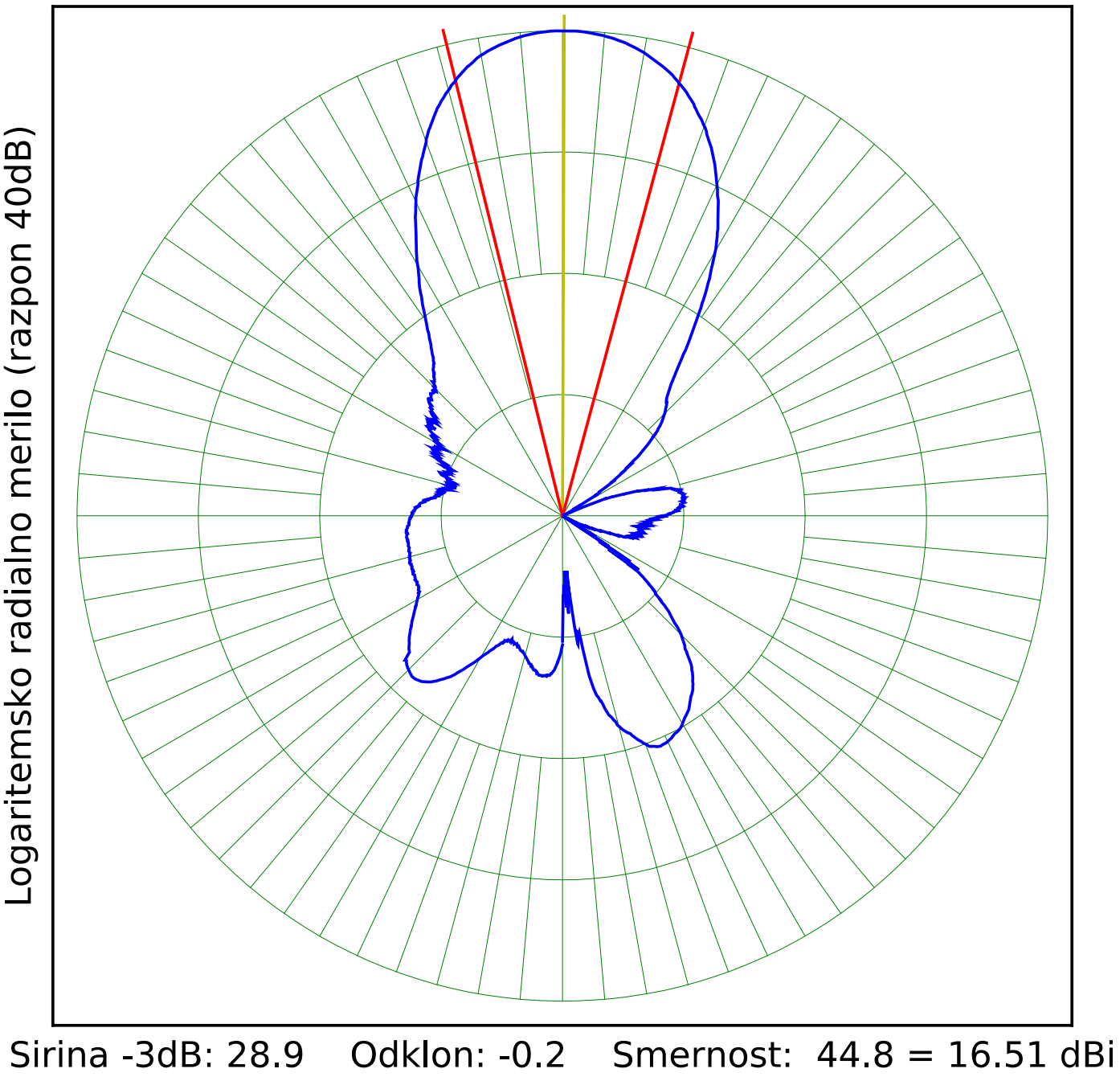
$$D_j=\frac{4\left|F\left(\Theta_{MAX}=0,\Phi_{MAX}=\Phi_j\right)\right|^2}{\int\limits_{-\pi}^{\pi}\left|F\left(\Theta,\Phi_j\right)\right|^2\sin|\Theta|\,d\,\Theta}\equiv delne\;smernosti$$

$$D=\frac{N}{\frac{1}{D_1}+\frac{1}{D_2}+\frac{1}{D_3}+\ldots+\frac{1}{D_N}}$$

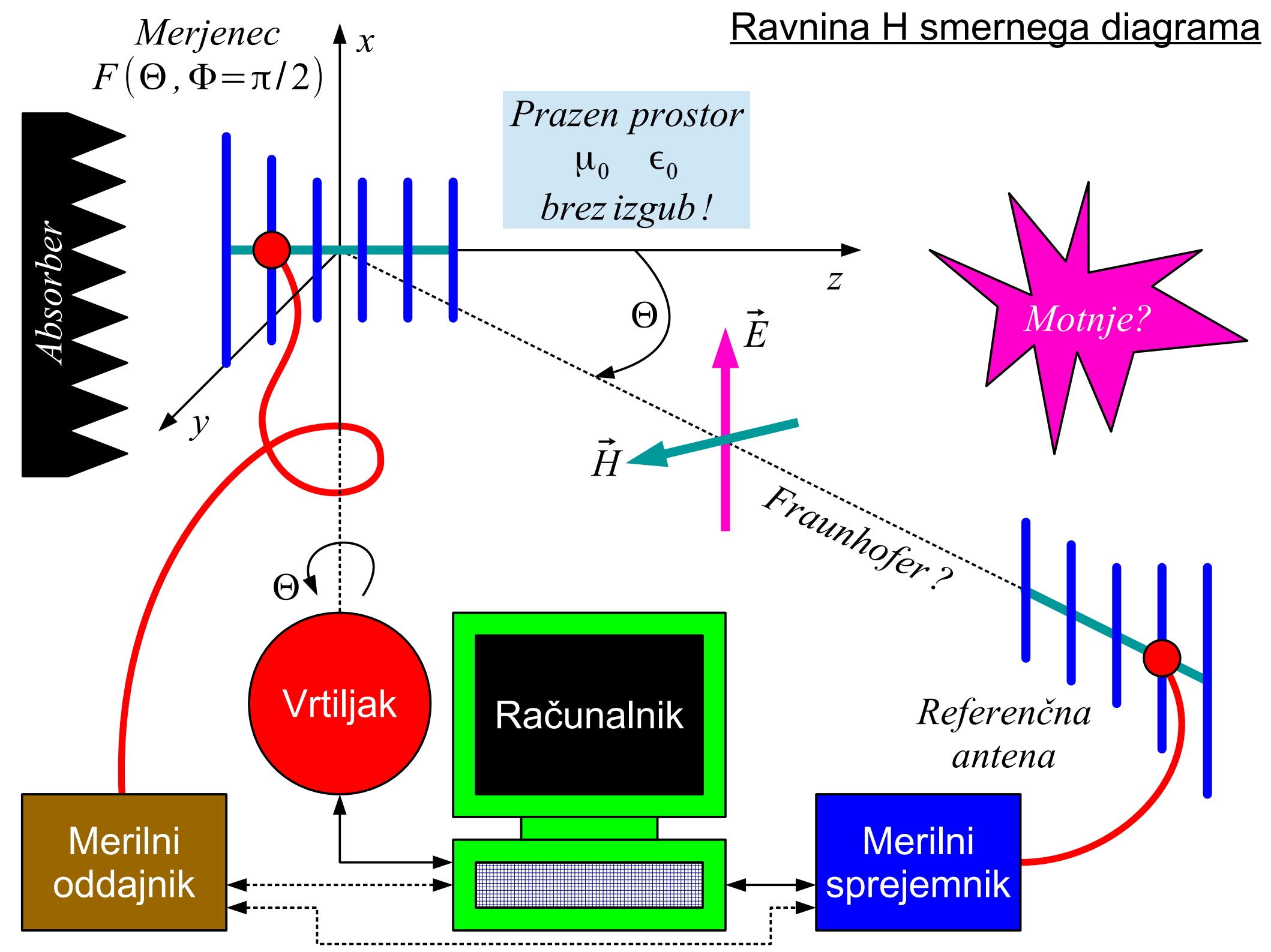
Integracija smernega diagrama

Ravnina E smernega diagrama

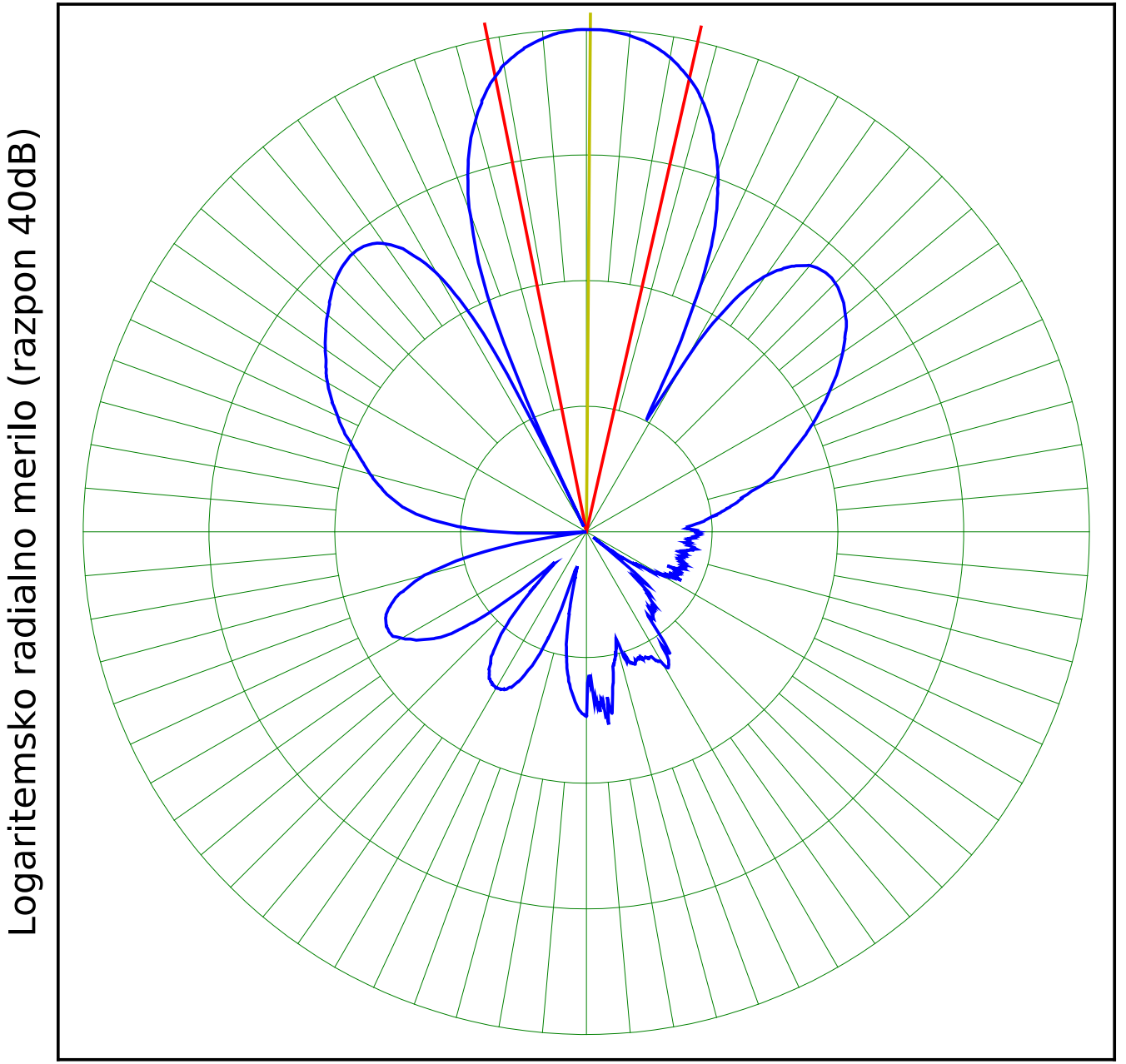



Sat Nov 25 19:46:46 2017
SBFA13 2360MHz ravnina E
Logaritemsko radialno merilo (razpon 40dB)
Sirina -3dB: 28.9 Odklon: -0.2 Smernost: 44.8 = 16.51 dBi

Ravnina H smernega diagrama

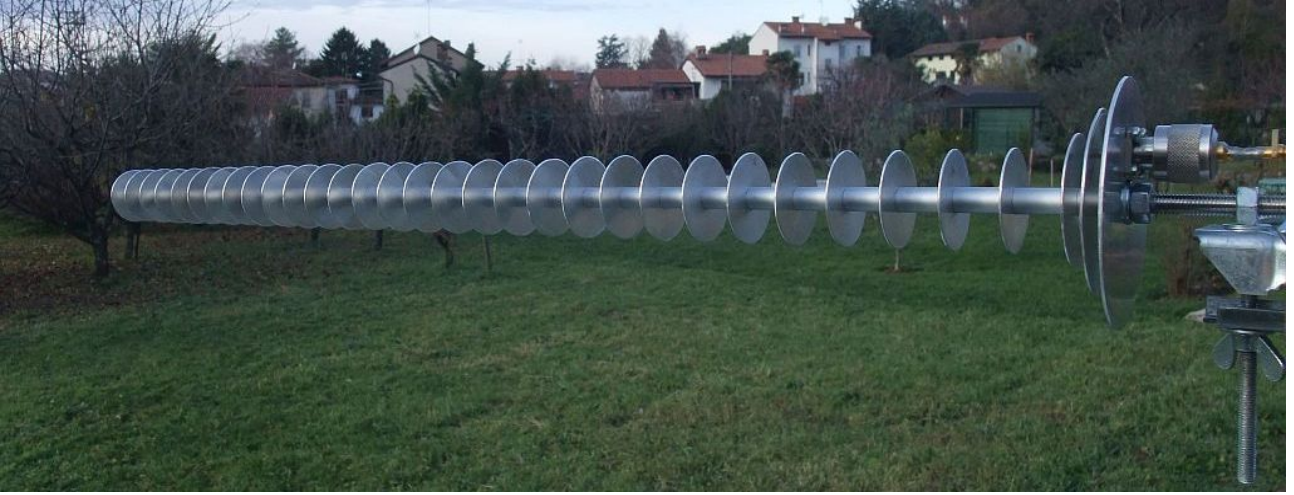


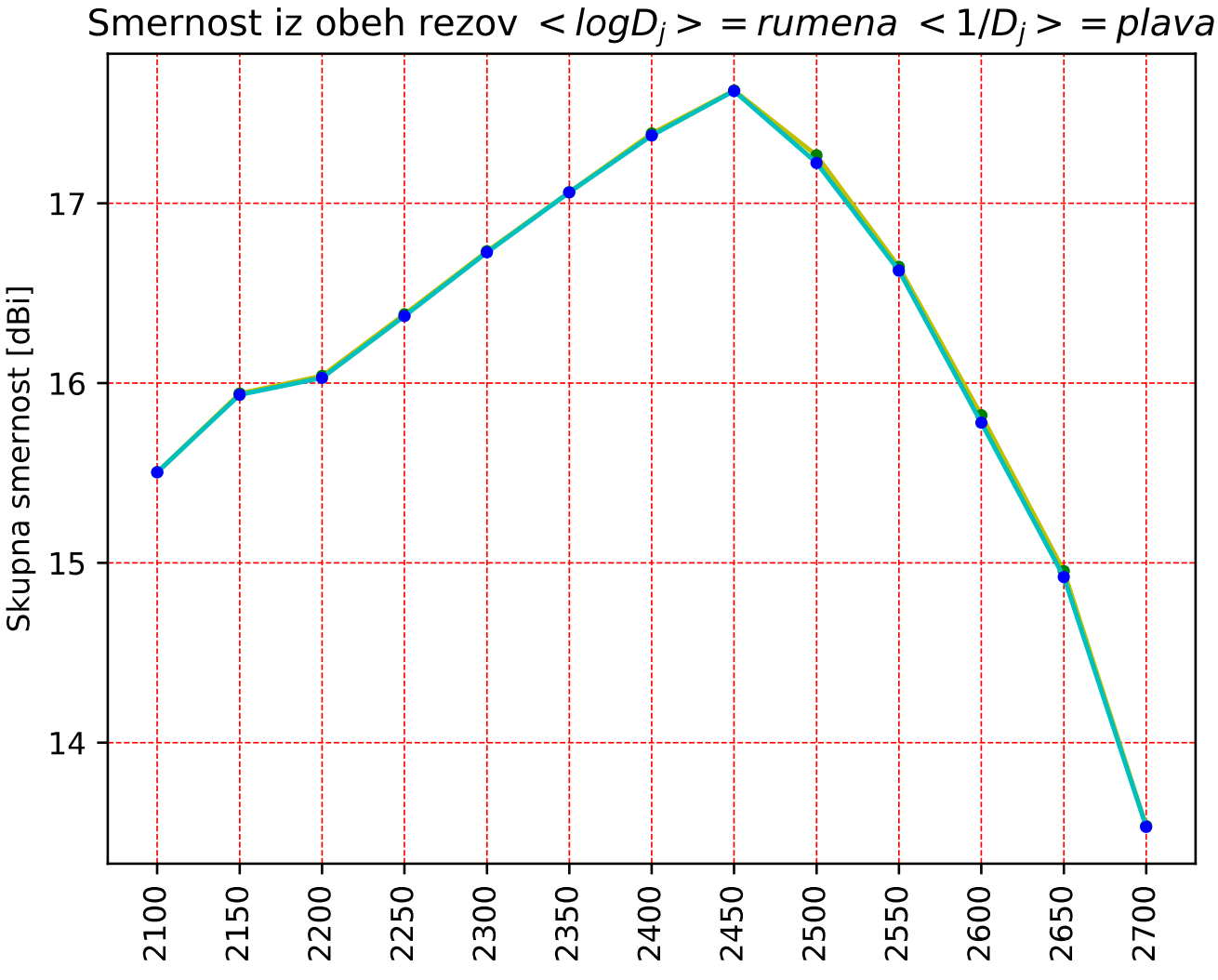
Sat Nov 25 19:37:17 2017
SBFA13 2360MHz ravnina H



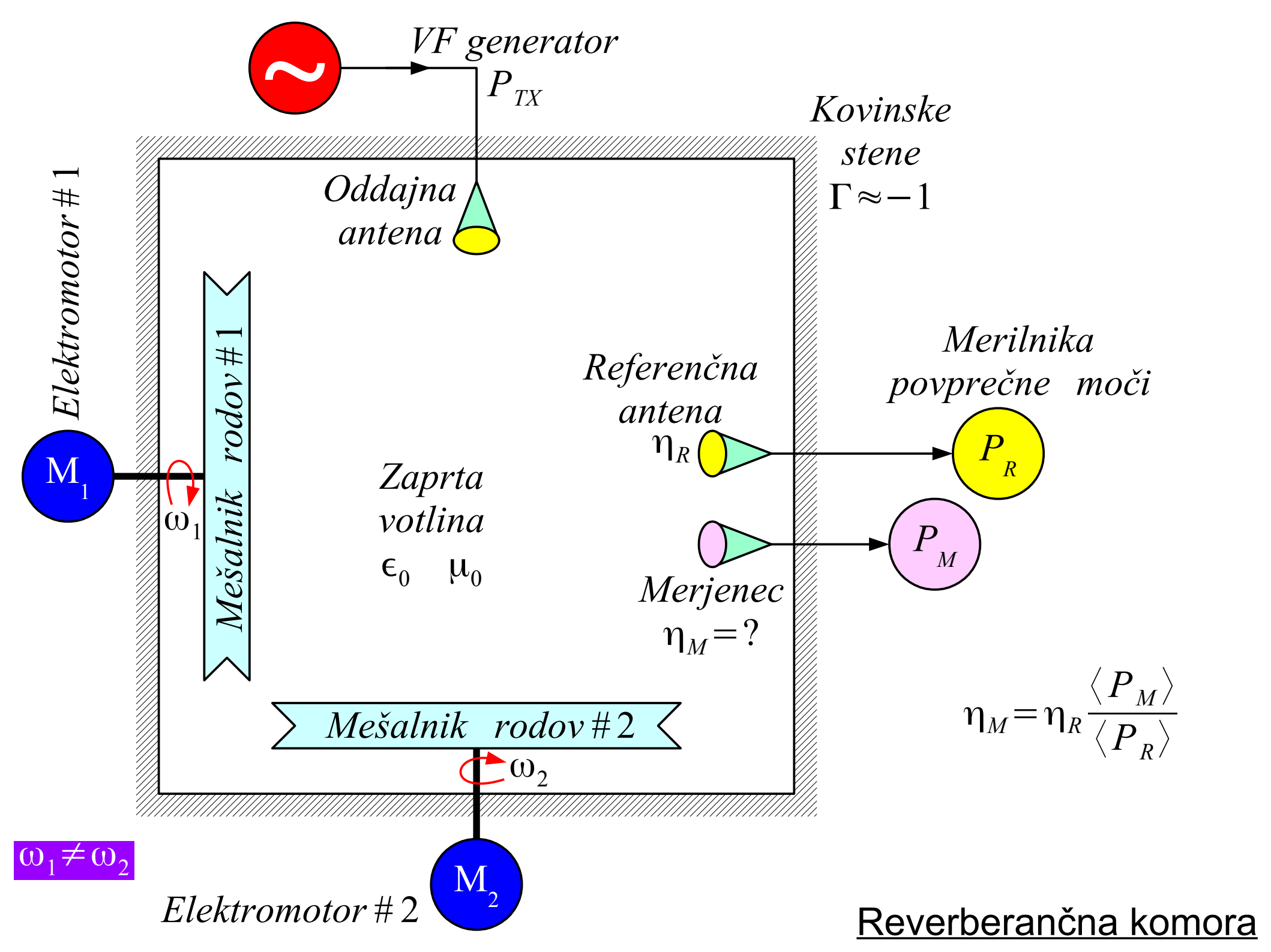
Sirina -3dB: 24.1 Odklon: -0.45 Smernost: 41.4 = 16.17 dBi

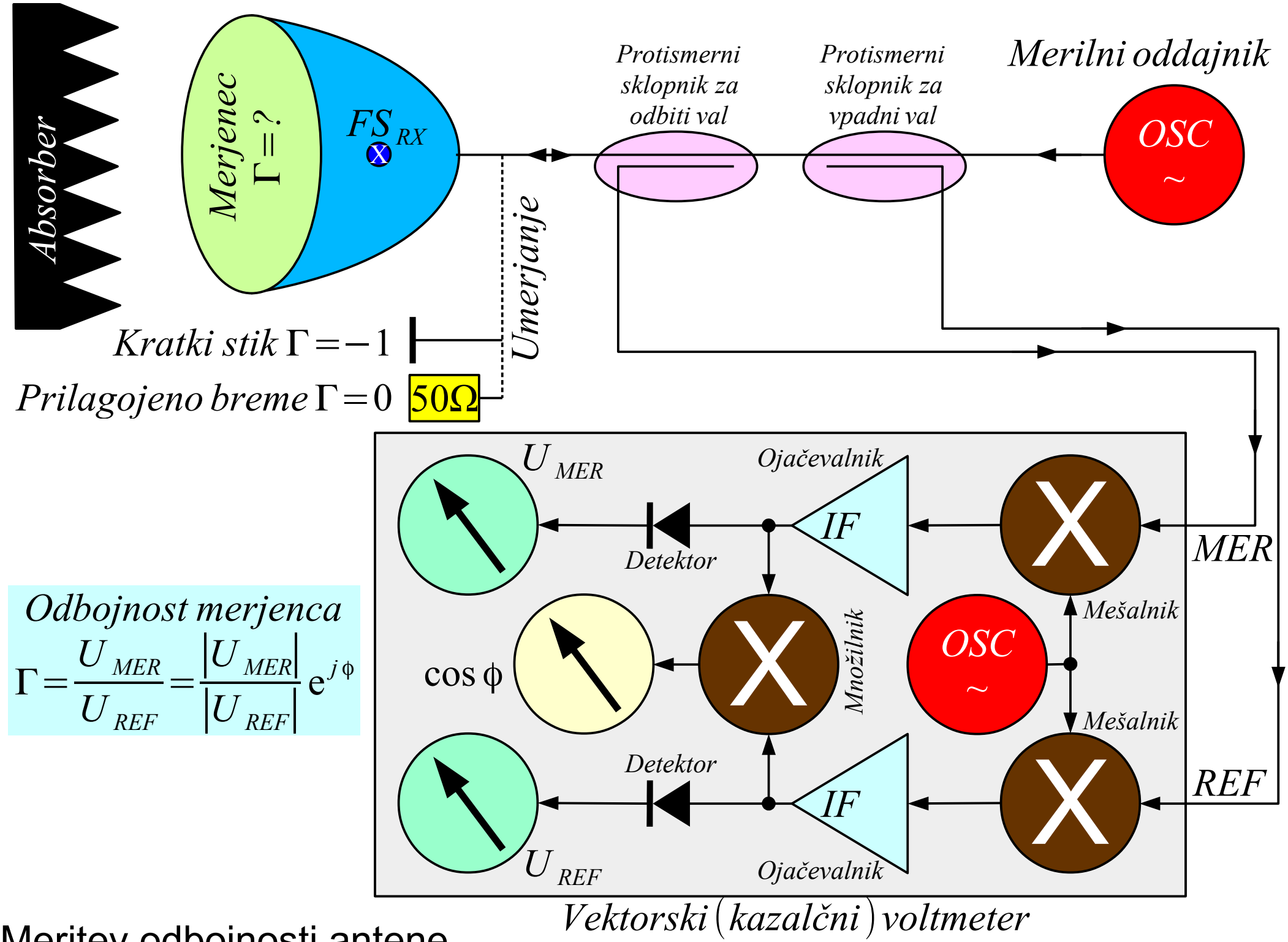
Mirujoči oddajnik in vrteči sprejemnik (merjenec)





Izmerjena smernost


VF generator
P_{TX}
Kovinske stene
$\Gamma \approx -1$
Oddajna antena
Elektromotor #1
M_1
ω_1
Mešalnik rodov #1
Referenčna antena
η_R
Merilnika povprečne moči
P_R
Zaprta votlina
ϵ_0 μ_0
P_M
Merjenec
$\eta_M = ?$
$\eta_M = \eta_R \frac{\langle P_M \rangle}{\langle P_R \rangle}$
Mešalnik rodov #2
ω_2
$\omega_1 \neq \omega_2$
M_2
Elektromotor #2
Reverberančna komora



Meritev odbojnosti antene

Impedanca $Z[\Omega]=R+jX$

Karakteristična impedanca (dogovorjeno)

$Z_K=50\,\Omega$

Odbojnost $\Gamma=\dfrac{Z-Z_K}{Z+Z_K}$

Povratno slabljenje (Return loss)

$\Gamma_{dB}=20\log_{10}|\Gamma|$

Valovitost (SWR)

$\rho=\dfrac{1+|\Gamma|}{1-|\Gamma|}$

Slabljenje neprilagoditve (Mismatch loss)

$a_{dB}=10\log_{10}\left(1-|\Gamma|^2\right)$

$a[\%]=\left(1-|\Gamma|^2\right)\cdot 100\,\%$

Neprilagoditev bremena

Z	Γ	Γ_{dB}	ρ	a_{dB}	$a[\%]$
0Ω	−1	0dB	∞	−∞dB	0%
1Ω	−0.96	−0.4dB	50	−13.6dB	7.7%
5.6Ω	−0.8	−1.9dB	9	−4.4dB	36%
10Ω	−0.67	−3.5dB	5	−2.6dB	56%
16.7Ω	−0.5	−6dB	3	−1.3dB	75%
25Ω	−0.33	−9.6dB	2	−0.5dB	89%
33.3Ω	−0.2	−14dB	1.5	−0.2dB	96%
50Ω	0	−∞dB	1	0dB	100%
66.7Ω	0.2	−14dB	1.5	−0.2dB	96%
100Ω	0.33	−9.6dB	2	−0.5dB	89%
150Ω	0.5	−6dB	3	−1.3dB	75%
250Ω	0.67	−3.5dB	5	−2.6dB	56%
450Ω	0.8	−1.9dB	9	−4.4dB	36%
2500Ω	0.96	−0.4dB	50	−13.6dB	7.7%
∞Ω	1	0dB	∞	−∞dB	0%
j50Ω	j	0dB	∞	−∞dB	0%
−j50Ω	−j	0dB	∞	−∞dB	0%
(50+j50)Ω	0.2+j0.4	−7dB	2.6	−1dB	80%
(50−j50)Ω	0.2−j0.4	−7dB	2.6	−1dB	80%