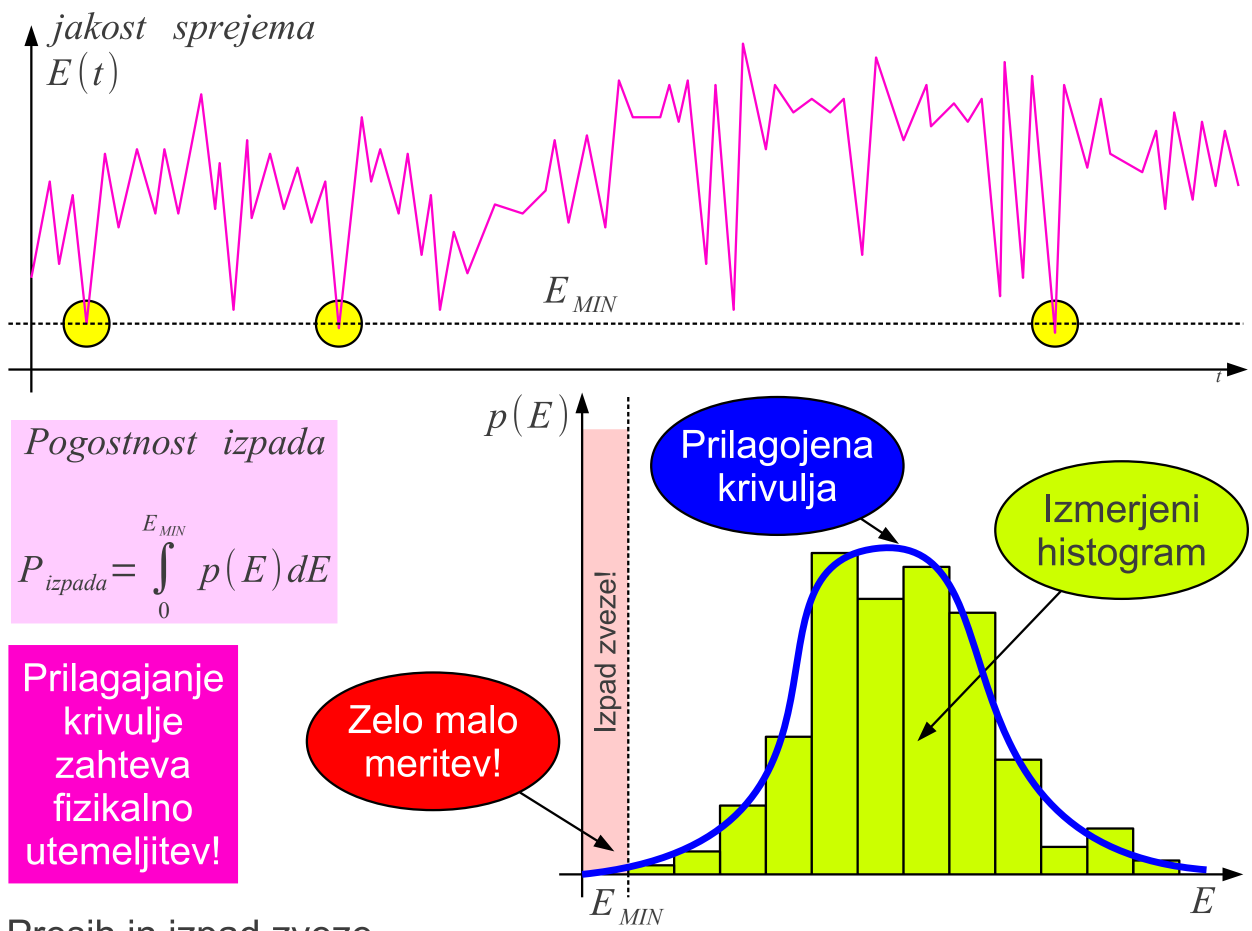
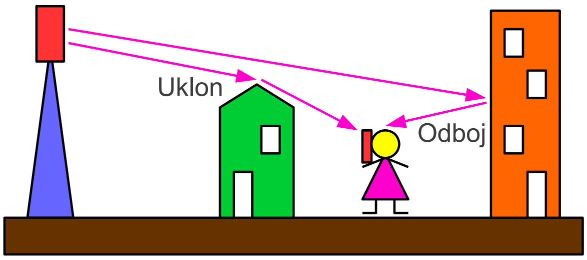
17. Večpotje v radijski zvezi

Večina nalog iz anten in razširjanje valov zahteva obravnavo v treh dimenzijah prostora. Tako skalarne kot tudi vektorske veličine so funkcije časa in vseh treh dimenzij prostora. Ozkopasovne signale $B \ll f$ radia največkrat smemo v izračunih ponazoriti s harmonskim signalom ene same krožne frekvence $\omega = 2\pi f$, kar poenostavi časovne odvode v $\partial / \partial t = j\omega$.

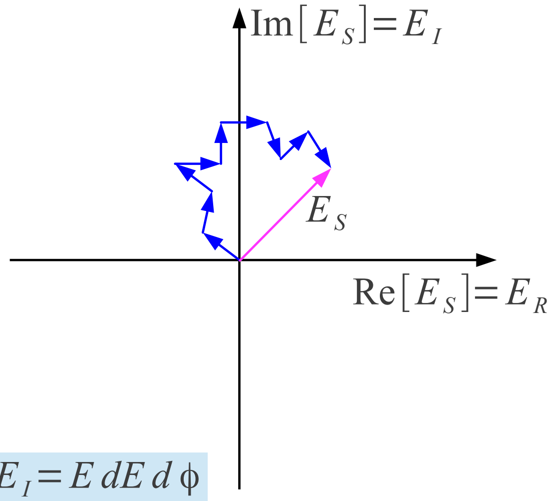


Presih in izpad zveze



Večpotje brez vidljivosti: Rayleigh ($\langle E^2 \rangle$)

vsota mnogo naključnih malih kazalcev



Gaussova porazdelitev komponent

$$p(E_R)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{E_R^2}{2\sigma^2}}$$

$$p(E_I)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{E_I^2}{2\sigma^2}}$$

$$E_S=E_R+jE_I=E\,e^{j\phi}$$

$$E=|E_S|$$

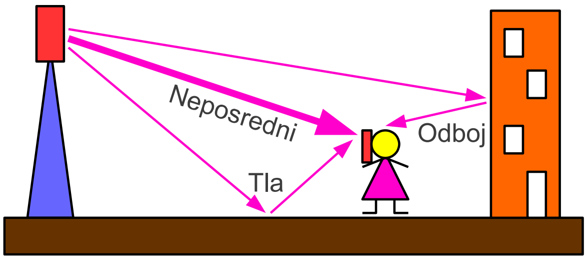
$$dE_R\,dE_I=E\,dE\,d\phi$$

$$p(E_R,E_I)=p(E_R)\,p(E_I)=\frac{1}{\sigma^2 2\pi}e^{-\frac{E_R^2+E_I^2}{2\sigma^2}}=p(E)\,p(\phi)$$

$$\langle E^2\rangle=2\sigma^2$$

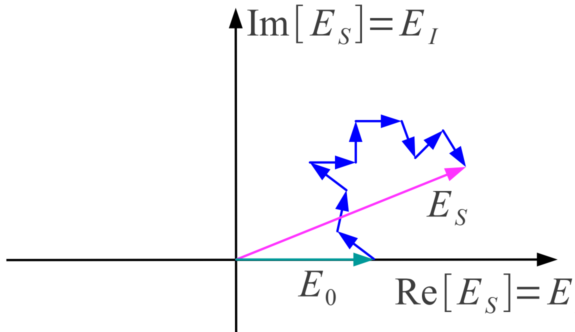
$$p(E)=\int_0^{2\pi}p(E_R,E_I)\,E\,d\phi=\int_0^{2\pi}\frac{1}{\sigma^2 2\pi}e^{-\frac{E^2}{2\sigma^2}}E\,d\phi=\frac{E}{\sigma^2}\mathrm{e}^{-\frac{E^2}{2\sigma^2}}=\frac{2E}{\langle E^2\rangle}\mathrm{e}^{-\frac{E^2}{\langle E^2\rangle}}$$

Rayleighjeva porazdelitev



Večpotje z neposrednim žarkom: Rice (E_0, σ)

en velik in mnogo naključnih malih kazalcev



Gaussova porazdelitev komponent

$$p(E_R)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(E_R-E_0)^2}{2\sigma^2}}$$

$$p(E_I)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{E_I^2}{2\sigma^2}}$$

$$E=|E_S|$$

$$E_S=E_R+jE_I=E\,e^{j\phi}$$

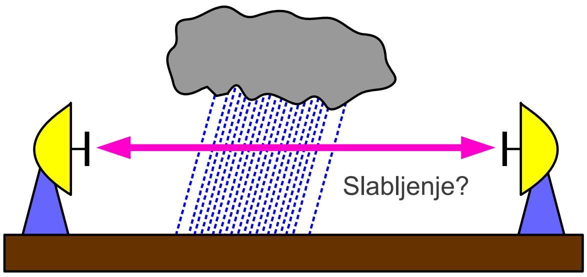
$$dE_R\,dE_I=E\,dE\,d\phi$$

$$p(E_R,E_I)=\frac{1}{\sigma^2 2\pi}e^{-\frac{(E_R-E_0)^2+E_I^2}{2\sigma^2}}=\frac{1}{\sigma^2 2\pi}e^{-\frac{E^2+E_0^2}{2\sigma^2}}e^{\left(\frac{E_R E_0}{\sigma^2}\right)}=\frac{1}{\sigma^2 2\pi}e^{-\frac{E^2+E_0^2}{2\sigma^2}}e^{\left(\frac{E_0 E}{\sigma^2}\right)\cos\phi}$$

$$p(E)=\int_0^{2\pi}p(E_R,E_I)\,E\,d\phi=\frac{E}{\sigma^2}\mathrm{e}^{-\frac{E^2+E_0^2}{2\sigma^2}}\mathrm{I}_0\left(\frac{E_0 E}{\sigma^2}\right)$$

$$\int_0^{2\pi}e^{\left(\frac{E_0 E}{\sigma^2}\right)\cos\phi}d\phi=2\pi\,\mathrm{I}_0\left(\frac{E_0 E}{\sigma^2}\right)$$

Riceova porazdelitev



Neznane razmere: log-normalna ($<E_{dB}>, \sigma_{dB}$)

Fizikalno neutemeljeno!

$$p(E_{dB}) = \frac{1}{\sigma_{dB}\sqrt{2\pi}} e^{-\frac{(E_{dB}-\langle E_{dB}\rangle)^2}{2\sigma_{dB}^2}}$$

$$E_{dB} = 20\log_{10}\left(\frac{|E_S|}{E_{REF}}\right) = 20\log_{10}\left(\frac{E}{E_{REF}}\right) = \frac{20}{\ln 10}\ln\left(\frac{E}{E_{REF}}\right)$$

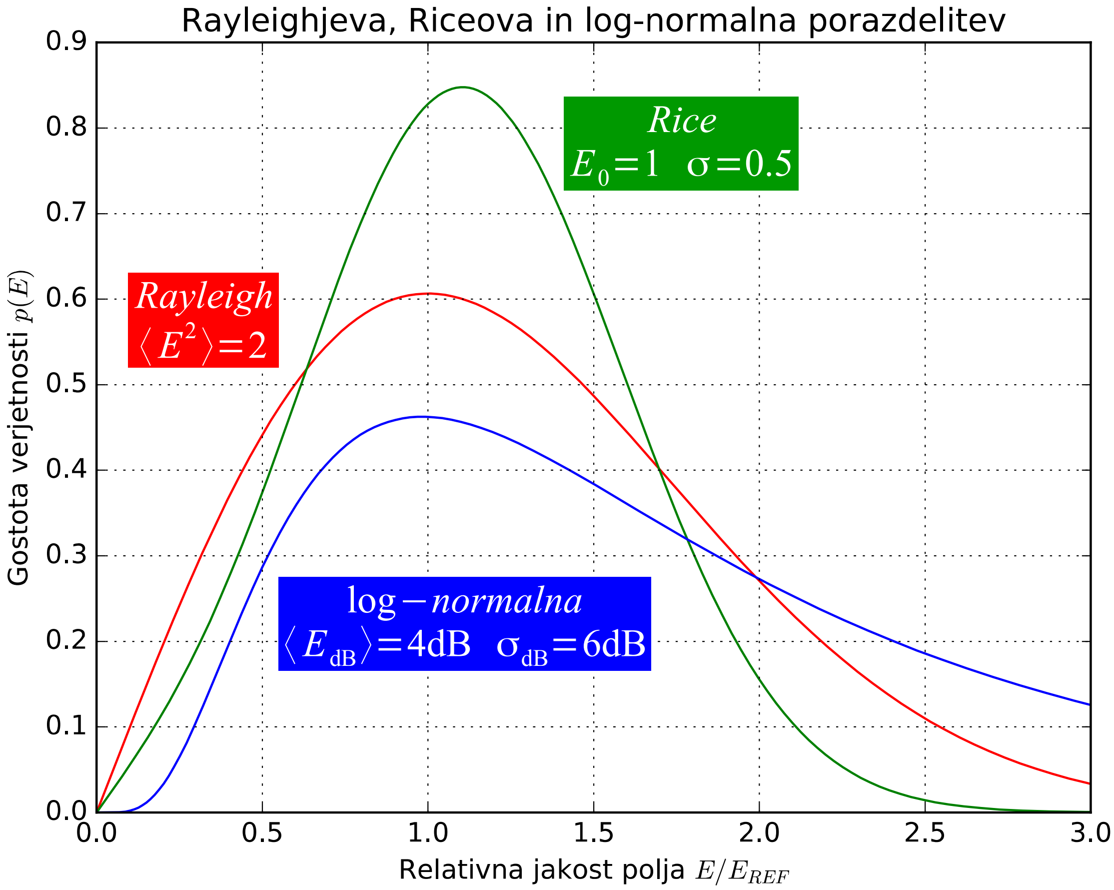
$$\sigma_{dB} = \sqrt{\left\langle \left(E_{dB} - \langle E_{dB}\rangle\right)^2\right\rangle}$$

$$\frac{dE_{dB}}{dE} = \frac{20}{\ln 10}\left(\frac{E_{REF}}{E}\right)\frac{1}{E_{REF}} = \frac{20}{E\ln 10}$$

$$p(E_{dB})\,dE_{dB} = p(E)\,dE$$

$$p(E) = p(E_{dB})\frac{dE_{dB}}{dE} = p(E_{dB})\frac{20}{E\ln 10} = \frac{20}{E(\ln 10)\sigma_{dB}\sqrt{2\pi}} e^{-\frac{\left[20\log_{10}\left(\frac{E}{E_{REF}}\right)-\langle E_{dB}\rangle\right]^2}{2\sigma_{dB}^2}}$$

Log-normalna porazdelitev


Rayleighjeva, Riceova in log-normalna porazdelitev
Rice
$E_0=1 \quad \sigma=0.5$
Rayleigh
$\langle E^2 \rangle = 2$
log−normalna
$\langle E_{dB} \rangle = 4dB \quad \sigma_{dB} = 6dB$
Gostota verjetnosti $p(E)$
Relativna jakost polja E/E_{REF}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0
0.5
1.0
1.5
2.0
2.5
3.0

* * * * *