Concept of Diversity Antenna Gain

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Motivation

Performance measure of diversity antennas

- MEG of each antenna
- correlation between antennas

  Two separated values $\Rightarrow$ difficult for comparison

Diversity Antenna Gain

- Single parameter as a performance measure
- Not unusual, but very reasonable

History

Theory

- Spatial correlation ('70s, Yeh)
- Relation between antenna pattern correlation and fading correlation (1984, Takeuchi)
- Mean effective gain (1990, Taga)
- *Diversity antenna gain* (2000, Ogawa)

History

Practice

- Antenna diversity has been mandatory in Japanese PDC system.
- So many studies have been made; some presented in IEEE AP-S and ISAP, but mostly in Japanese only.
- Antenna-oriented study; radiation pattern, efficiency and return loss.
- MEG and correlation are not used so often among antenna engineers in Japan, as neither propagation nor diversity scheme are the teritory of them.

MEG

$$G_e = \frac{1}{1+X} \int_0^{2\pi} \int_0^{\pi} (XG_\theta P_\theta + G_\varphi P_\varphi)\, \mathrm{d}\Omega$$

- Ω : solid angle
- X : cross polarization power ratio
- G_θ **and** G_φ : θ- and φ-polarization components of the antenna power gain (incl. radiation efficiency and impedance mismatch loss)
- P_θ **and** P_φ : angular power spectra of θ- and φ-polarization components

Radiation Pattern Correlation

= Fading Correlation

$$\rho_{e12} = \frac{\left| \frac{1}{1+X} \int_0^{2\pi} \int_0^{\pi} \left(X E_{\theta 1} E_{\theta 2}^{*} P_\theta + E_{\varphi 1} E_{\varphi 2}^{*} P_\varphi \right) \mathrm{d}\Omega \right|^2}{G_{e1} G_{e2}}$$

$E_{\theta k}$ **and** $E_{\varphi k}$: complex directivities of k-th antenna for θ and φ polarizations

$$\begin{aligned} G_{\theta k} &= |E_{\theta k}|^2 \\ G_{\varphi k} &= |E_{\varphi k}|^2 \end{aligned}$$

MEG and Correlation

Two sets of diversity antennas for the comparison

	Diversity antennas A	Diversity antennas B
G_{e1}	0 dBi	0 dBi
G_{e2}	-3 dBi	0 dBi
ρ_{e12}	0.1	0.8

Question

Which diversity antennas perform better, and how much?

$\Downarrow$

DAG is the answer!

MRC Diversity

Why MRC?

- Optimum in noise-limited environment
- Easy to compute the preformance

2-branch fading correlation matrix

$$\overline{\mathbf{R}} = \Gamma_0 \begin{bmatrix} G_{e1} & \sqrt{G_{e1} G_{e2} \rho_{e12}} \\ \sqrt{G_{e1} G_{e2} \rho_{e12}} & G_{e2} \end{bmatrix}$$

Γ_0 : signal to noise ratio for a ideal dual-polarized isotropic antenna (MEG $= 0$ dB)

MRC Diversity

eigenvalues of $\overline{\mathbf{R}} = \lambda_1,\ \lambda_2$

$\Rightarrow$ uncorrelated branches with branch power of λ_1 and λ_2

PDF, CDF and BER are given in closed forms of λ_1 *and* λ_2*.*

Two Definitions of DAG

DAG-OP : Slow fading $\Rightarrow$ outage probability

gain of Γ_0 *to satisfy the specified outage probability*

DAG-BER : Fast fading $\Rightarrow$ average BER

gain of Γ_0 *to satisfy the specified average BER*

Example

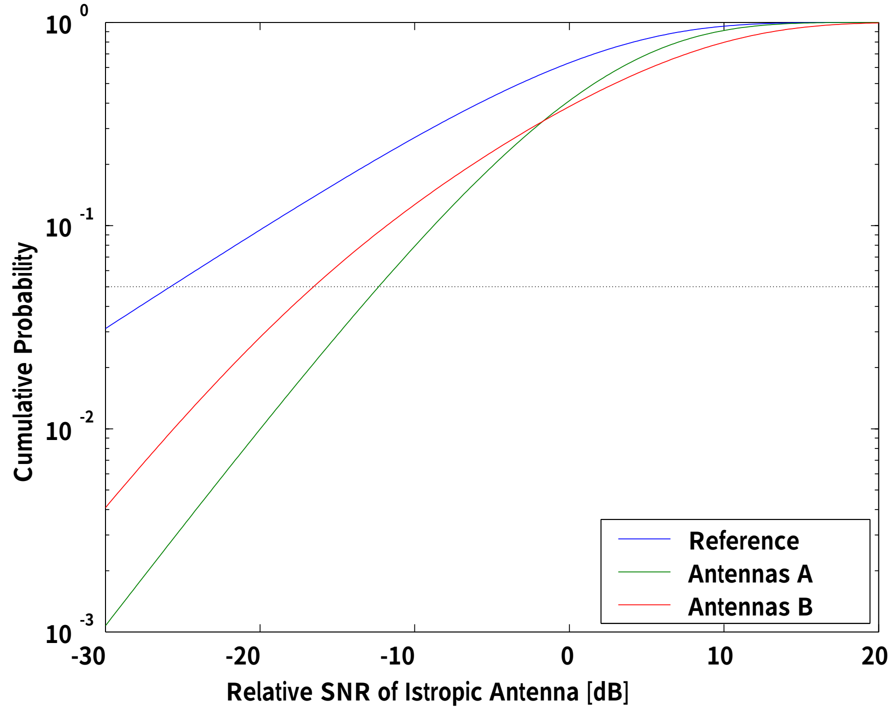
Two sets of diversity antennas for the comparison

	Diversity antennas A	Diversity antennas B
G_{e1}	0 dBi	0 dBi
G_{e2}	-3 dBi	0 dBi
ρ_{e12}	0.1	0.8

DAG-OP and DAG-BER are compared.

Example of DAG-OP

CDF of output SNR of diversity antennas

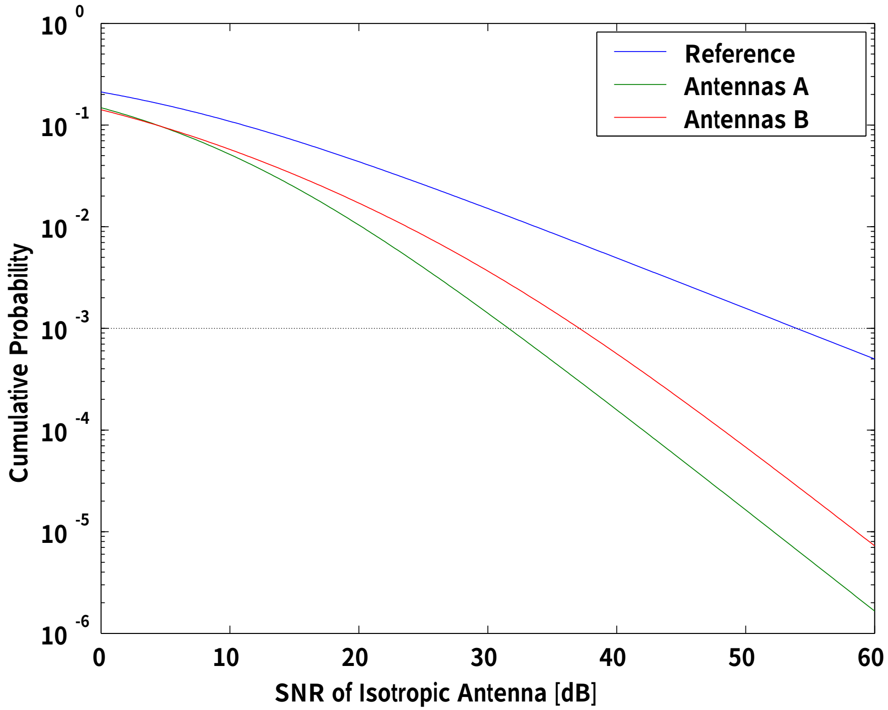


outage probability 5 %

DAG-OP$_A = 22.4$ dB $>$ DAG-OP$_B = 16.9$ dB

Example of DAG-BER

Average BER of diversity antennas



BER 1.0×10^{-3}

$\text{DAG-BER}_\text{A} = 13.5$ dB $>$ $\text{DAG-BER}_\text{B} = 9.3$ dB

Conclusions

- DAG can directly express the diversity performance under some specific environment and some specific modem and some specific diversity schem.
- DAG value depends on which criteria the user needs. In case of DAG-BER, the value becomes smaller if the required BER is higher.
- This devinition is almost trivial, but it is still necessary to clearly present the definition.