RÁDIÓS IRÁNYMEGHATÁROZÁS

GYAKORLAT

2015-11-04.

JELTERJEDÉS.

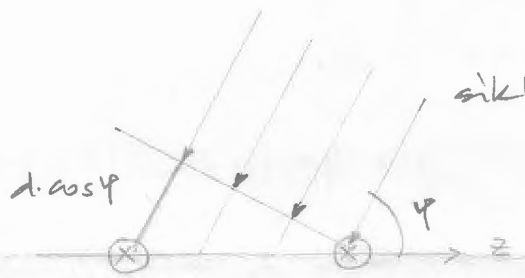
— modulált jel: $s(t) \cdot e^{j\omega t}$

— jelterjedés.

JEL: ADÓ: $e^{j\omega t}$, VEVŐ: $r(t) = e^{j\omega(t-\tau)} = e^{j\omega(t-\frac{s}{c})}$

FÁZIS: $\Delta\varphi = -\omega \frac{s}{c} = -2\pi f \frac{s}{c} = -2\pi \frac{s}{\lambda}$

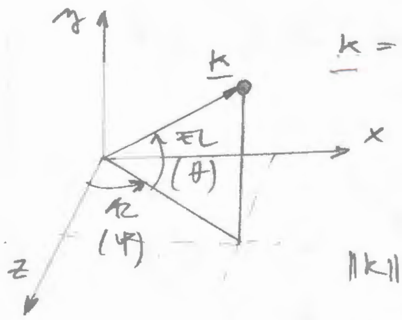
KÉT ANTENNA.



$$\Delta\varphi = -2\pi \cdot \frac{s}{\lambda} = -2\pi \frac{d \cdot \cos\varphi}{\lambda} = -\frac{2\pi}{\lambda} d \cdot \cos\varphi$$

FÁZISKÜLÖNBSÉG ÁLTALÁNOSAN:

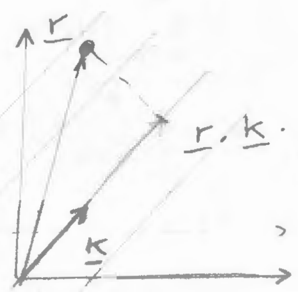
— JEL BEÉRKEZÉSÉNEK IRÁNYA (↑Z ADÓ)



$\underline{k} = a \cdot [\sin\varphi \cos\theta, \sin\varphi \sin\theta, \cos\varphi]$

$\|k\| = \frac{2\pi}{\lambda}$

— FÁZISVISZONY

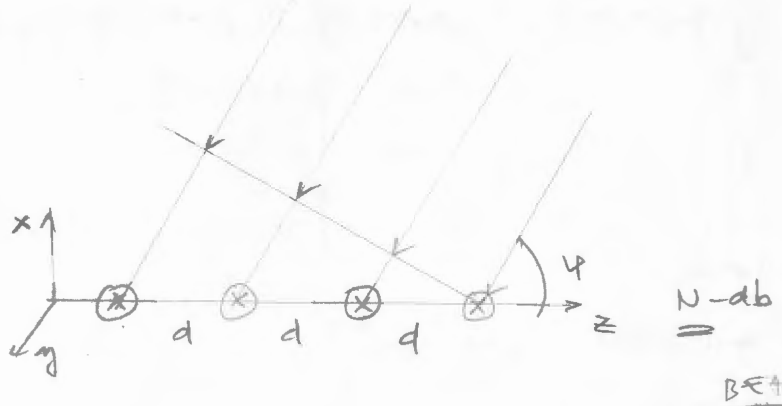


$\underline{r}$ · vevő antenna helye

$$\Delta\varphi = -2\pi \cdot \frac{s}{\lambda} = -\frac{2\pi}{\lambda} \cdot s = -\frac{2\pi}{\lambda} \cdot \underline{r} \cdot \underline{k} \cdot \frac{1}{\|k\|} = -\underline{r} \cdot \underline{k}$$

ULA

spatial diversity (antenna)



$r_n = [0, 0, n \cdot d]$

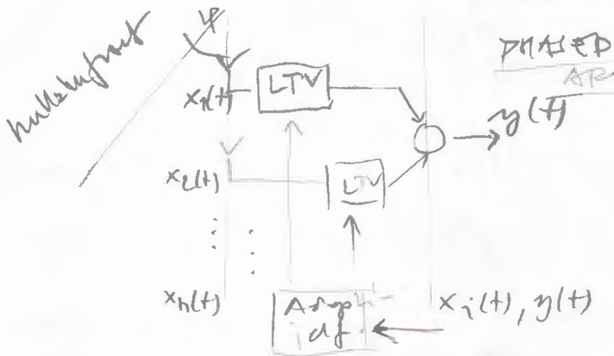
$\underline{k} = a \cdot [\sin\varphi, \varnothing, \cos\varphi]$

$\|k\| = \frac{2\pi}{\lambda} = a \cdot 1$

$a = \frac{2\pi}{\lambda}$

$\Delta\varphi_n = -\underline{k} \cdot \underline{r}_n = \frac{2\pi}{\lambda} \cdot n \cdot d \cdot \cos\varphi$

BEAMFORMING



PHASED ARRAY

STEERING VECTOR

- fázisviszonyok (φ, θ) függvényében)
- ULA

$$\underline{a}(\varphi) = [1, e^{-j\frac{2\pi}{\lambda} d \cdot \cos\varphi}, \dots, e^{-j\frac{2\pi}{\lambda}(N-1)d}]$$

$$a_n(\varphi) = e^{-j\frac{2\pi}{\lambda}(n-1) d \cdot \cos\varphi}$$

vétel több antennával

$\underline{M}$ db jel $s_m(t)$, φ_m irányból $m = 1..M$

$$\boxed{\underline{x}(t) = \underset{N \times M}{\underline{\underline{A}}}\, \underline{s}(t) + \underline{n}(t)} = [\underline{a}(\varphi_1), \underline{a}(\varphi_2) \dots \underline{a}(\varphi_M)] \cdot \begin{bmatrix} s_1(t) \\ s_2(t) \\ \vdots \\ s_M(t) \end{bmatrix} + \underline{n}(t)$$

BEAMFORMING

w_i : $y(t) = \sum_{i=1}^{N} w_i^* \cdot x_i(t) = \underline{w}^H \underline{x}(t)$

teljesítmény: $P(\underline{w}) = \frac{1}{N}\sum_{t=0}^{k} |y(t)|^2 = \frac{1}{N}\sum_{t=0}^{k} \underline{w}^H \underline{x}(t) \cdot \underline{x}^H(t) \cdot \underline{w} =$

$$\underline{w}^H \left[\frac{1}{N}\sum_{t=0}^{k} \underline{x}(t) \cdot \underline{x}^H(t)\right] \underline{w} = \underline{w}^H \hat{\underline{\underline{R}}} \cdot \underline{w}$$

maximális teljesítmény: $\underline{w} = \underline{a}(\varphi)$

MUSIC

$L = 4$
$M = 2$

ermitikus
hermit – matrix

ALTÉR:

$\underline{x} = A(\phi)\, s + n$

jeltér

n dim komplex
altér

vett jel autokovarianciá
mátrixa:

$$R = E\{\underline{x} \cdot \underline{x}^H\} = E\{\underline{\underline{A}}\,\underline{s} \cdot \underline{s}^H \cdot \underline{A}^H\} + E\{\underline{n}\,\underline{n}^H\} =$$

$$\underline{\underline{A}} \cdot E\{\underline{s} \cdot \underline{s}^H\} \cdot \underline{\underline{A}}^H + E\{\underline{n}\,\underline{n}^H\} = \underline{\underline{A}} \cdot \underline{\underline{S}}\,\underline{\underline{A}}^H + \delta^2 \underline{\underline{I}} = \underline{\underline{R}}_s + \delta^2 \underline{\underline{I}}$$

$\underline{\underline{R}}_s \rightarrow [N \times N]$

$\text{rank}\{\underline{\underline{R}}_s\} = M$ } $\rightarrow N - M$ 0 sajátértékkel tartozó sajátvektor q_m

$A x = \lambda x$

$A \cdot x = 0 \cdot x$

$$R_s \cdot q_m = A S A^H \cdot q_m = 0$$

$$\rightarrow q_m^H A S A^H \cdot q_m = 0$$

pozitív definit
$$\rightarrow A^H \cdot q_m = \underline{\underline{0}}$$

$$Q_n \in q_m \quad [N \times (N - M)]$$

PSEUDO SPEKTRUM:

$$P(\varphi) = \frac{1}{\sum_{m=1}^{N-M} \left| \left(a^H(\varphi) \cdot q_m \right) \right|^2} = \frac{1}{a^H(\varphi)\, Q_n \cdot Q_n^H\, a(\varphi)}$$

↑
jel hol van a maximum ϕ – ben

VALÓS ALKALMAZÁS.

ADÓ: $s^t(t) \cdot e^{j(\omega^t t + \varphi^t)} = r(t)$

VEVŐ: $s^r(t) = r(t-\tau) \cdot e^{-j(\omega^r t + \varphi^r)} =$

$$= s^t(t-\tau) \cdot e^{j(\omega^t (t-\tau) + \varphi^t)} \cdot e^{-j(\omega^r t + \varphi^r)} =$$

$$= s^t(t-\tau) \cdot e^{j(\omega^t t - \omega^t \tau + \varphi^t)} \cdot e^{-j(\omega^r t + \varphi^r)} =$$

$$= s^t(t-\tau) \cdot e^{j[(\omega^t - \omega^r)t - \omega^t \tau + \varphi^t - \varphi^r]}$$

$$\Phi(t) = (\omega^t - \omega^r)t - \omega^t \tau + (\varphi^t - \varphi^r)$$

```
function [P,phs_out,M] = music(r, K)

% load('data/data_00.mat');
% [P,phs,M] = music(r,0);
% plot(radtodeg(phs),abs(P));

c = 299792458;
f = 2.472e9;

phs = (-90:0.5:90)/180*pi;
r = transpose(r);

% --- antenna parameters

N = 8;          % antenna array size
d = 0.06;       % in meteres

% --- covariance matrix

R = complex(zeros(N,N));
L = size(r,2);
for i = 1:L
    R = R + r(:,i) * r(:,i)';
end
R = R/L;

% --- eigenvalues, eigenvectors

[E,l] = eig(R);
[lambdas,idx] = sort(abs(diag(l)));

if K == 0
    [~,K] = max(diff(log10(lambdas+1e-3)));
end
M = N - K;      % signal number

En = E(:,idx(1:K));

% --- pseudo spectrum

P = complex(zeros(1,length(phs)));
nn = (0:N-1)'; % index vector

for i = 1:length(phs)
    a = exp(-1i* 2*pi*f/c * d * sin(phs(i)) * nn);
    P(i) = 1/(a'*En*En'*a+eps);
end;

phs_out = phs/pi * 180;
```