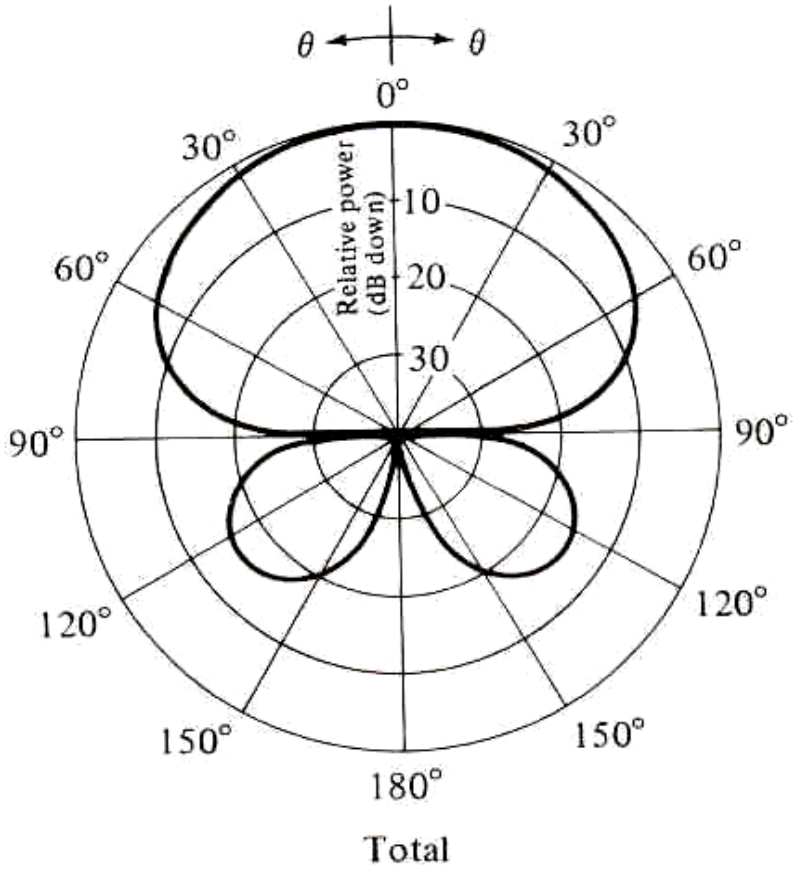
Dipolske skupine



Mobitel d.d.,
izobraževanje

8. 5. 2009,
predavanje 14

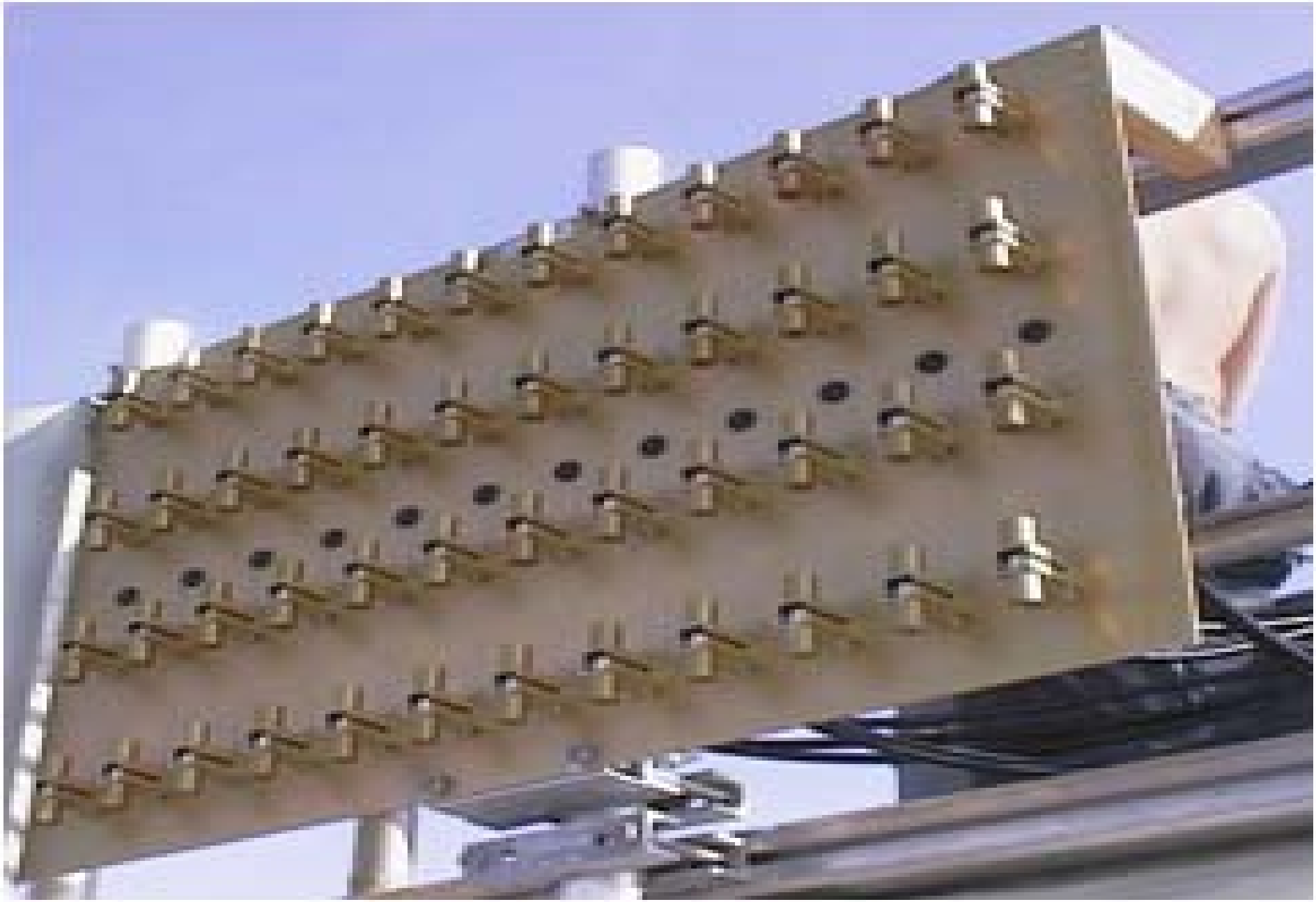
Prof. dr. Jožko Budin

Vsebina

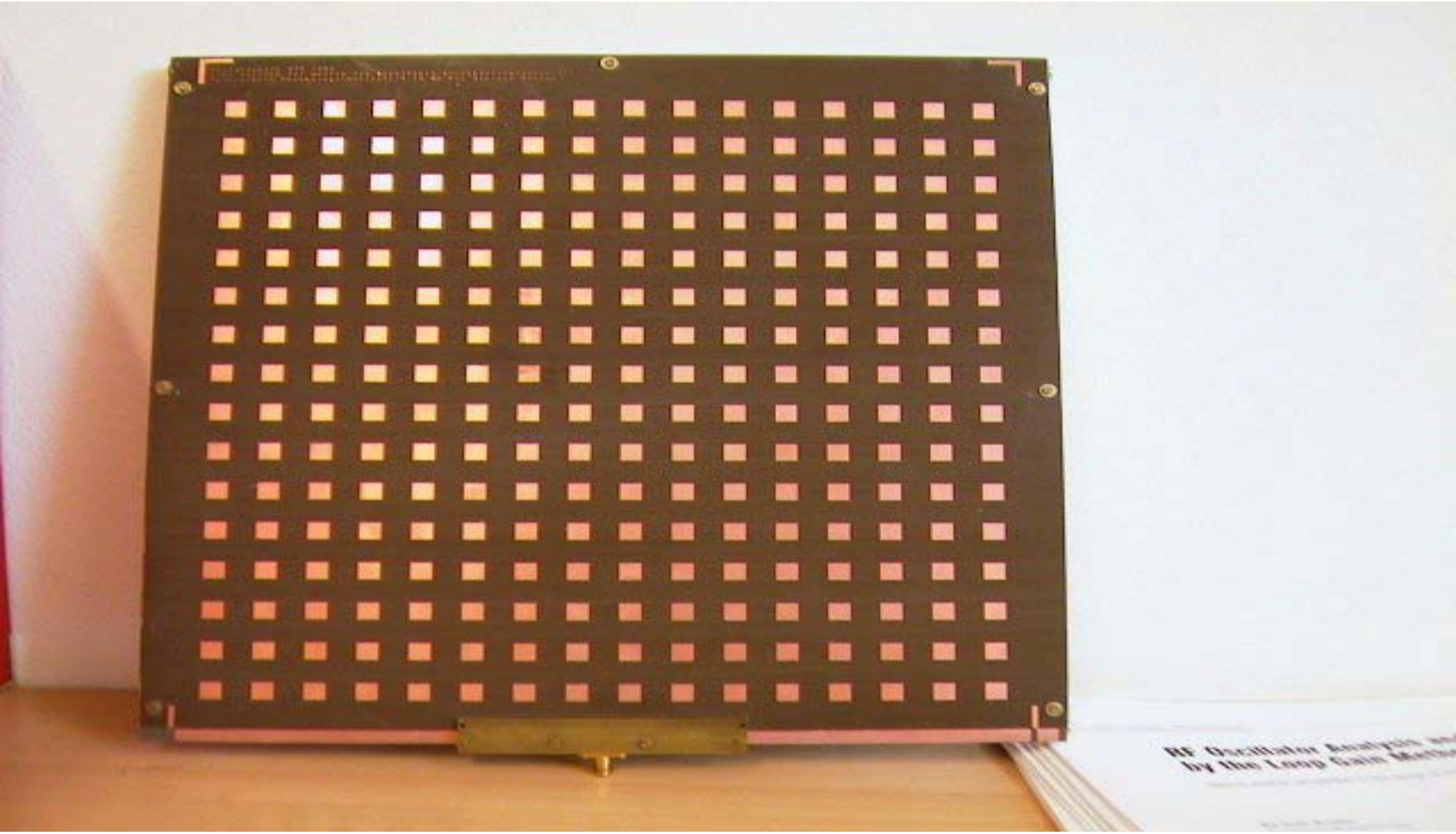
- Diskretne linearne in planarne skupine
- Pravilo o faktorizaciji smernih diagramov
- Dvo- in večelementne skupine dipolov
- Distribucija amplitude vzbujanja:
  - Konstantna distribucija amplitude
  - Upadajoče distribucije amplitude
- Fazno odklanjanje diagrama
  - Električno odklanjanje glavnega snopa
  - Optično odklanjanje glavnega snopa
- Pogreški vzbujanja skupin
- Adaptivne antene

Projekt radioastronomske skupine

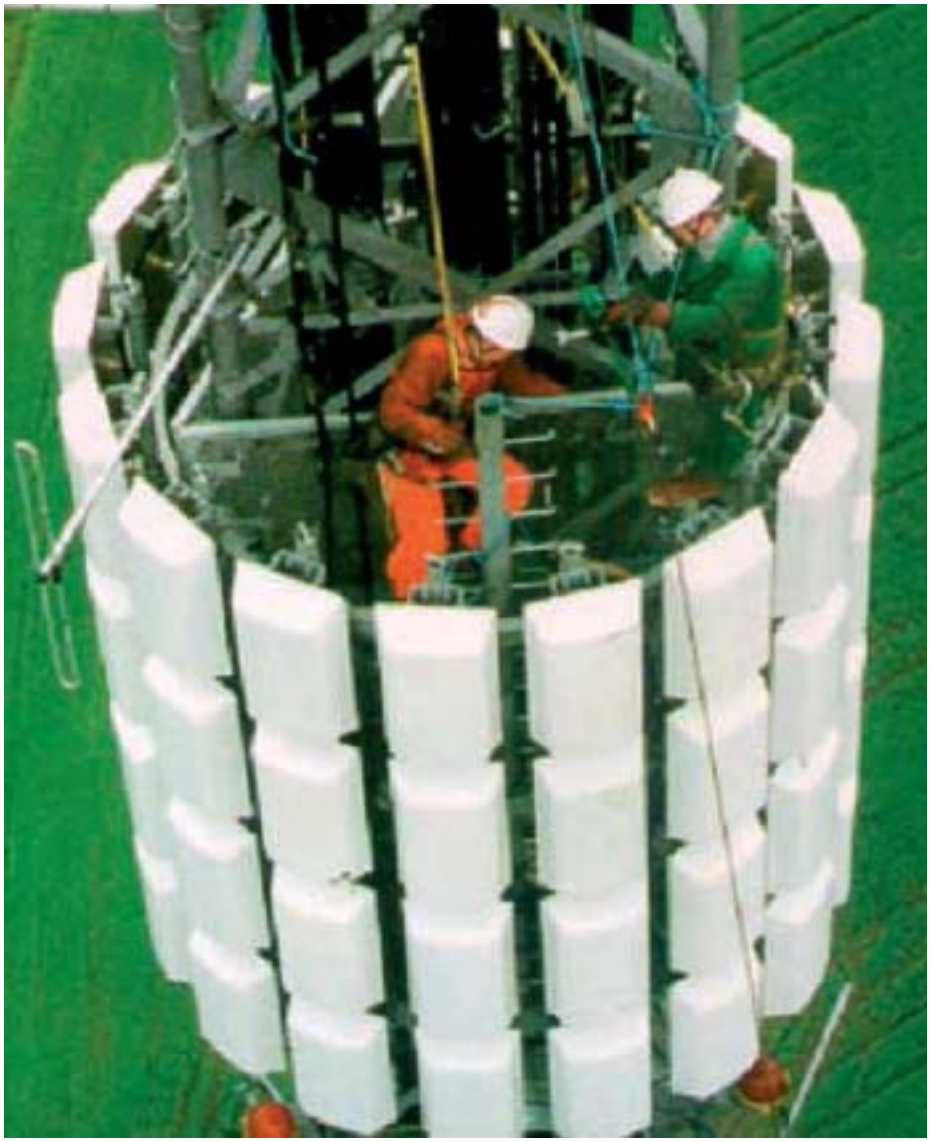
Planarna skupina širokopasovnih dipolov



Skupina krpičasih anten

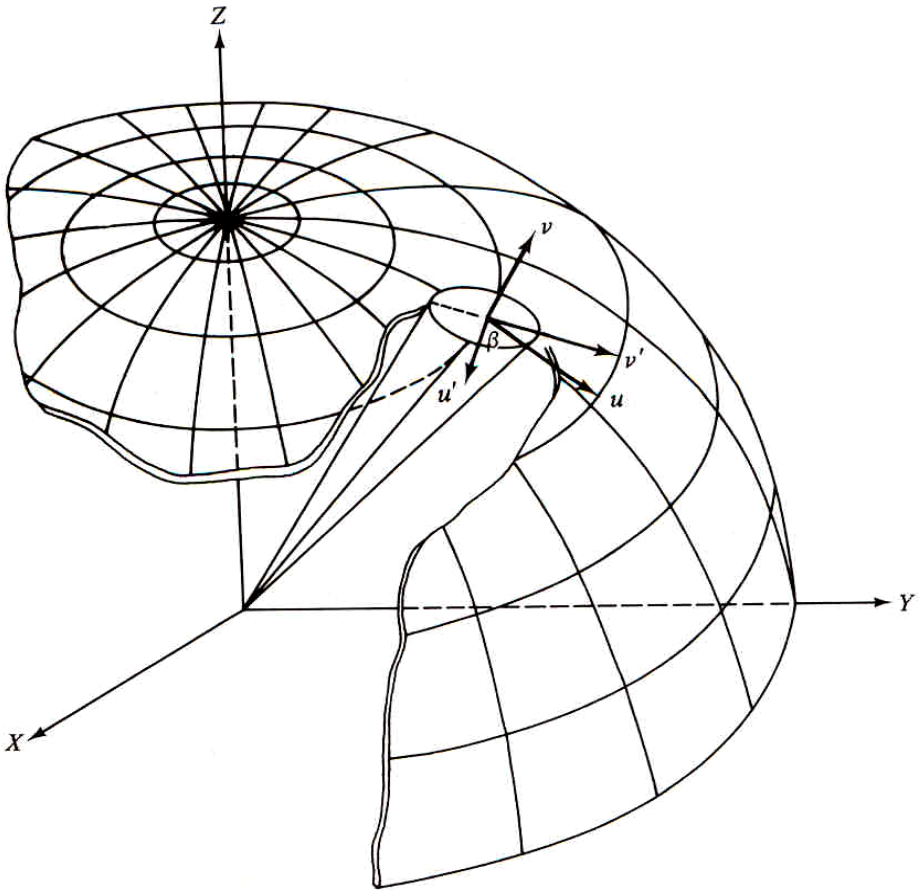


Antenske skupine v telekomunikacijah



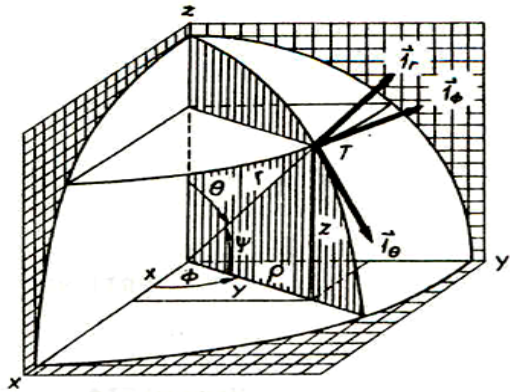
Projekt skupine SKA

Krogelni koordinatni sistem in smerni kosinusi



Sevanje anten v prostor obravnavamo v krogelnem koordinatnem sistemu. S projekcijo enotinega radialnega vektorja sledijo smerni kosinusi, ki nastopajo v formulah za smerne diagrame antenskih skupin.

KROGELNI KOORDINATNI SISTEM



$$\vec{1}_x = \vec{1}_r \sin\theta\cos\phi + \vec{1}_\theta \cos\theta\cos\phi - \vec{1}_\phi \sin\phi$$

$$\vec{1}_y = \vec{1}_r \sin\theta\sin\phi + \vec{1}_\theta \cos\theta\sin\phi + \vec{1}_\phi \cos\phi$$

$$\vec{1}_z = \vec{1}_r \cos\theta - \vec{1}_\theta \sin\theta$$

$$\vec{1}_r = \vec{1}_x \sin\theta\cos\phi + \vec{1}_y \sin\theta\sin\phi + \vec{1}_z \cos\theta$$

$$\vec{1}_\theta = \vec{1}_x \cos\theta\cos\phi + \vec{1}_y \cos\theta\sin\phi - \vec{1}_z \sin\theta$$

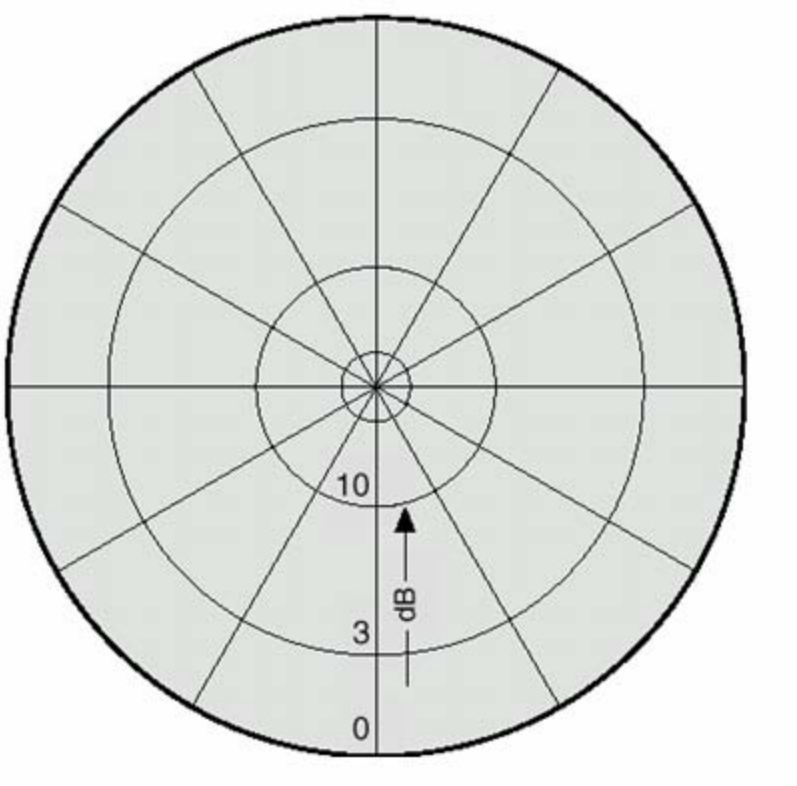
$$\vec{1}_\phi = -\vec{1}_x \sin\phi + \vec{1}_y \cos\phi$$

$$\cos\theta_x = \frac{x}{r} = \sin\theta\cos\phi$$

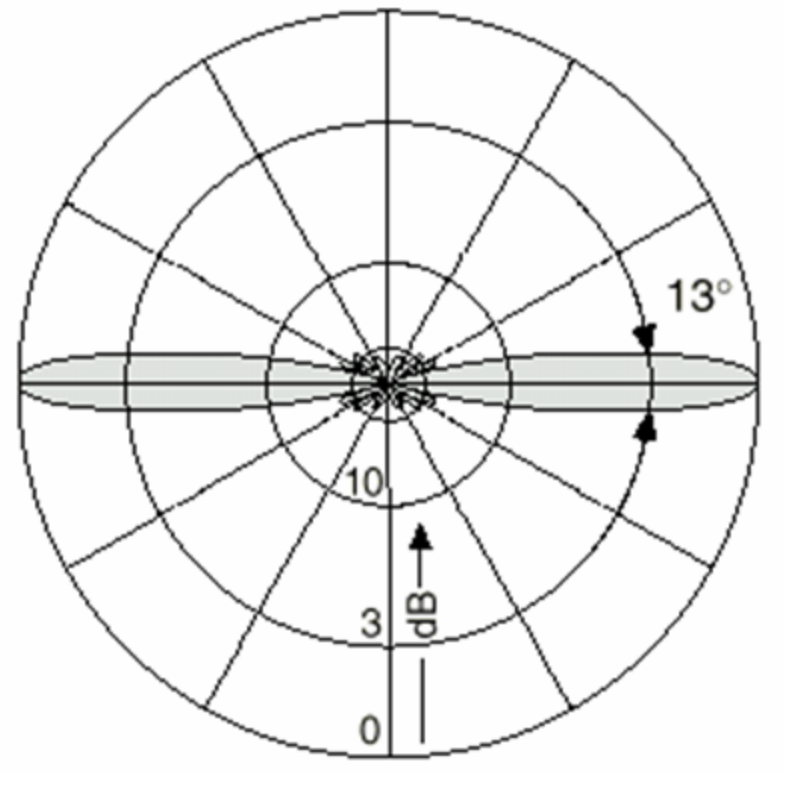
$$\cos\theta_y = \frac{y}{r} = \sin\theta\sin\phi$$

$$\cos\theta_z = \frac{z}{r} = \cos\theta$$

Vsesmerni diagram v horizontalni ravnini

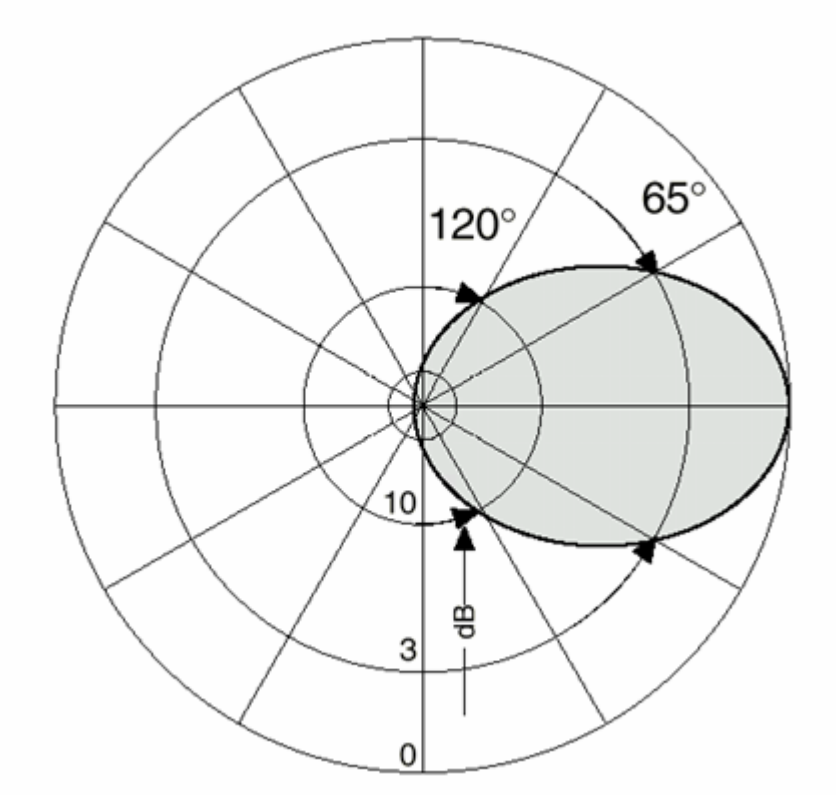


Horizontalna ravnina

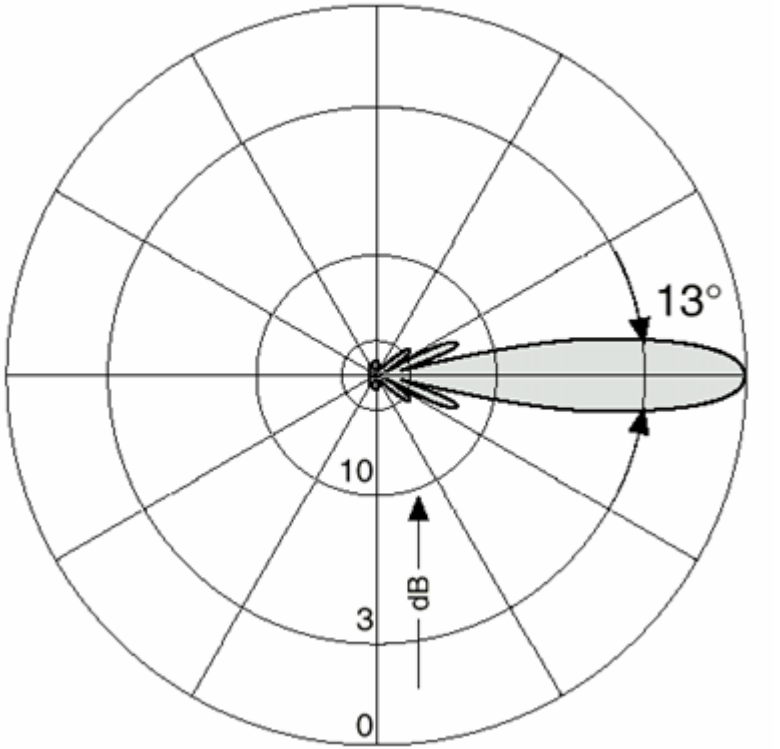


Vertikalna ravnina

Usmerjen diagram v horizontalni ravnini



Horizontalna ravnina



Vertikalna ravnina

Vrste skupin

1. Po porazdelitvi:
   - Zvezno porazdeljeni viri
   - Diskretno porazdeljeni viri
2. Po geometriji:
   - Enodimenzionalne (linearne, preme) skupine
   - Dvodimenzionalne (ploskovne, površinske) skupine
   - Trodimenzionalne (prostorske) skupine
3. Po topologiji virov:
   - Skupine ekvidistantnih virov
   - Skupine neekvidistantnih virov
   - Skupine naključno porazdeljenih virov
4. Po virih:
   - Skupine izotropnih virov
   - Skupine neizotropnih virov
5. Po načinu vzbujanja faze:
   - Stacionarne skupine
   - Fazno krmiljene skupine
6. Po načinu vzbujanja amplitude:
   - Konstantna porazdelitev
   - Upadajoča porazdelitev
7. Po obliki ploskve virov:
   - Pravokotna ploskev
   - Krožna ploskev
   - Eliptična ploskev

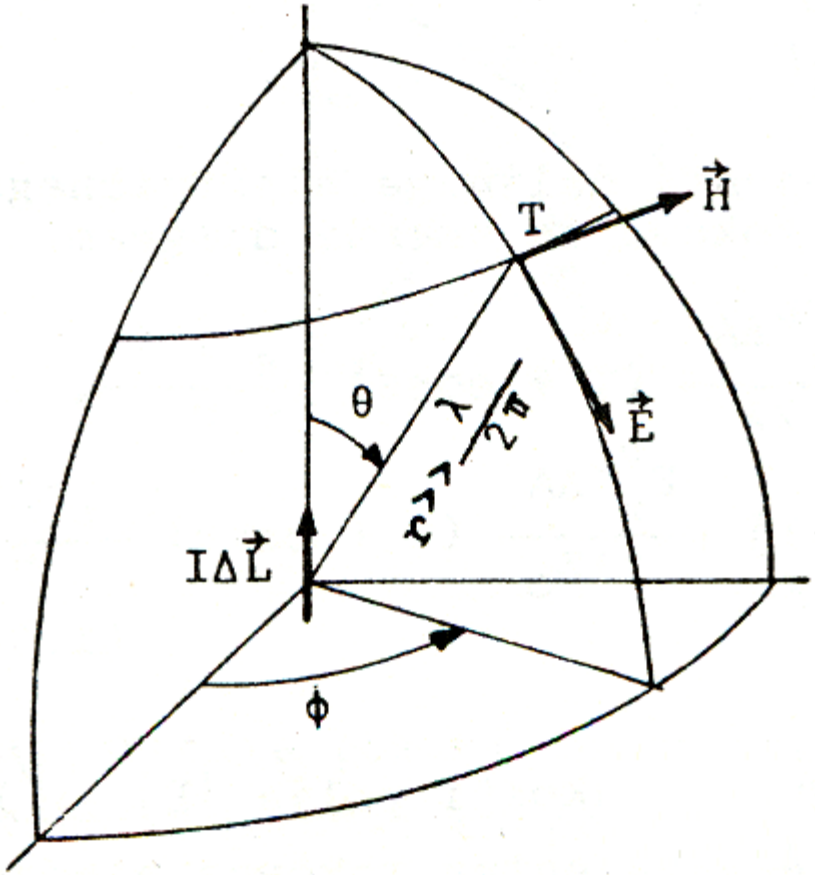
Porazdelitve amplitude

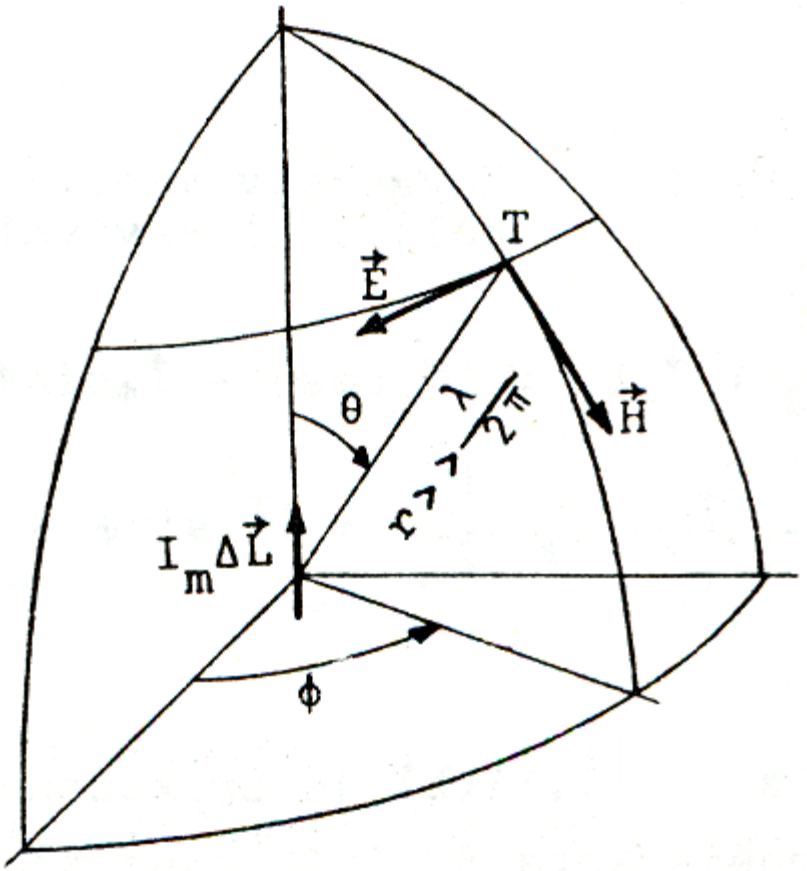
- Konstantna porazdelitev
- Dvignjen kosinus
- Parabolna upadajoča porazdelitev
- Dolph-Čebišev
- Binomska porazdelitev
- Taylor

Polje računske sonde

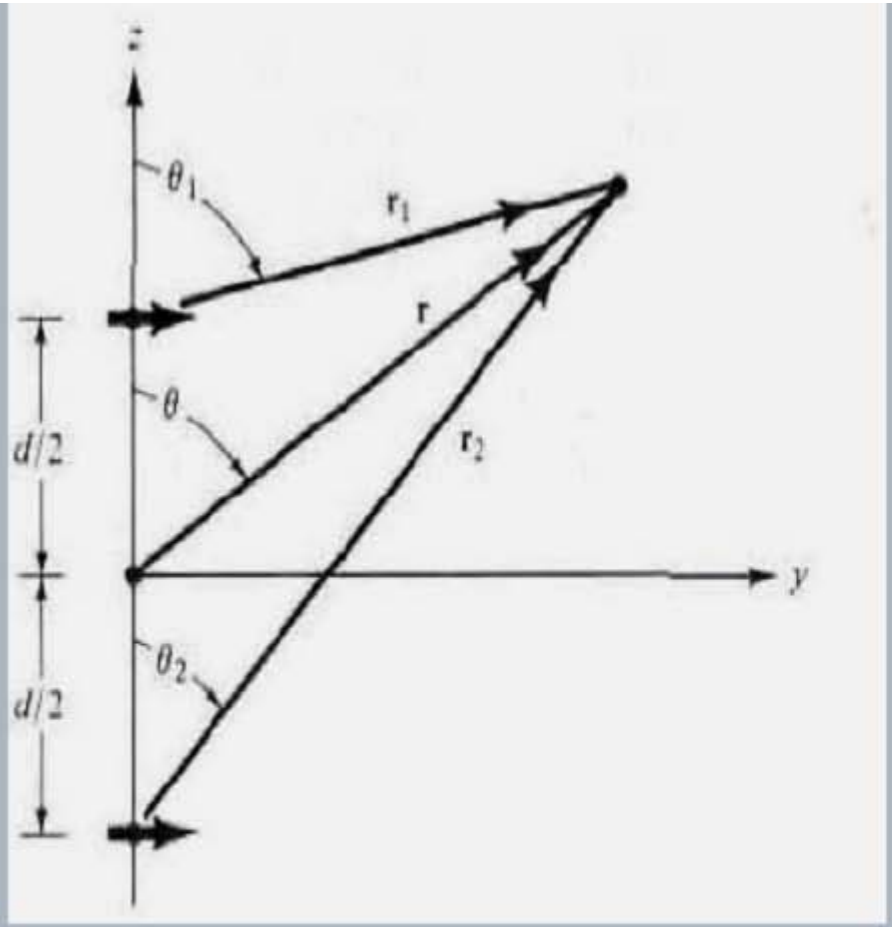
$$\vec{E} = \vec{1}_\theta E_\theta = \vec{1}_\theta j Z_o \frac{I\Delta L}{2\lambda} \sin\theta \frac{e^{-jkr}}{r}, \quad \vec{E} = \vec{1}_\phi E_\phi = -\vec{1}_\phi j \frac{I_m \Delta L}{2\lambda} \sin\theta \frac{e^{-jkr}}{r},$$

$$\vec{H} = \vec{1}_\phi \frac{E_\theta}{Z_o} = \vec{1}_\phi j \frac{I\Delta L}{2\lambda} \sin\theta \frac{e^{-jkr}}{r}, \quad \vec{H} = -\vec{1}_\theta \frac{E_\phi}{Z_o} = \vec{1}_\theta j \frac{I_m \Delta L}{2\lambda Z_o} \sin\theta \frac{e^{-jkr}}{r}.$$





Skupina dveh elementov



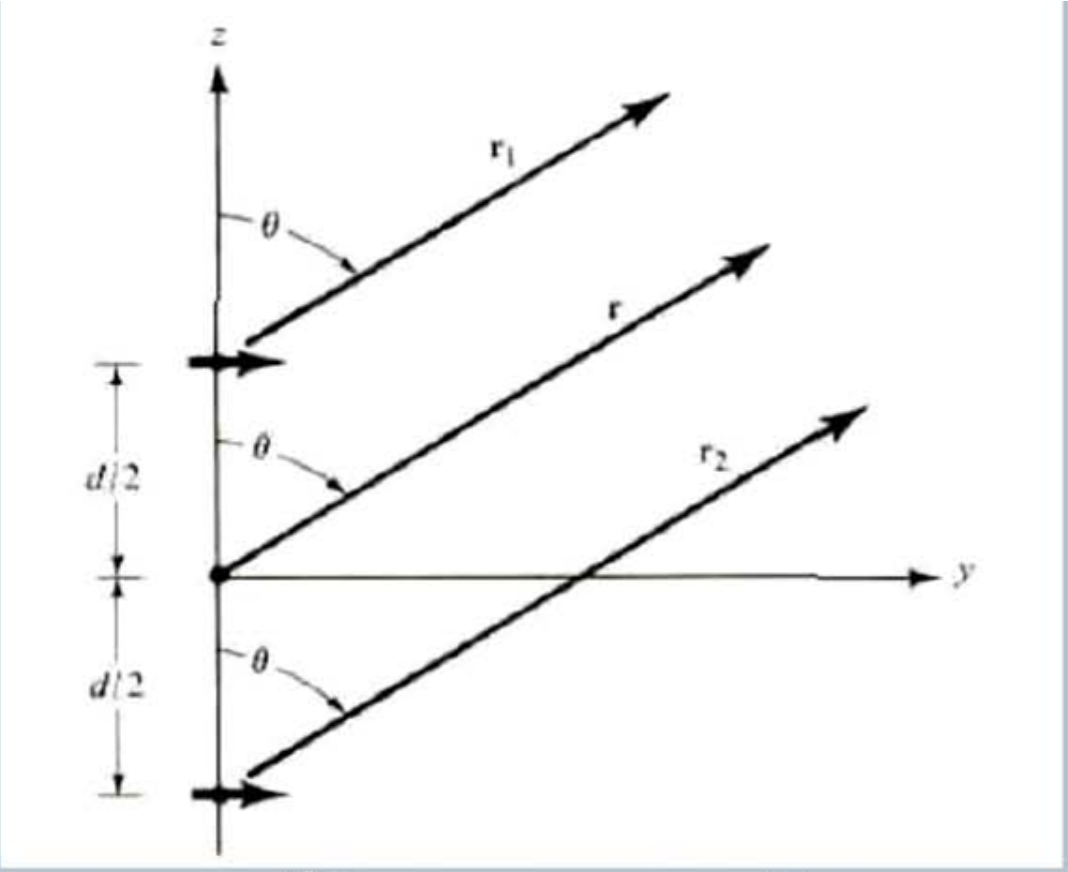
$$\theta_1 \cong \theta_2 \cong \theta$$

$$r_1 \cong r_2 \cong r - \frac{d}{2}\cos\theta$$

$$r_1 \cong r_2 \cong r$$

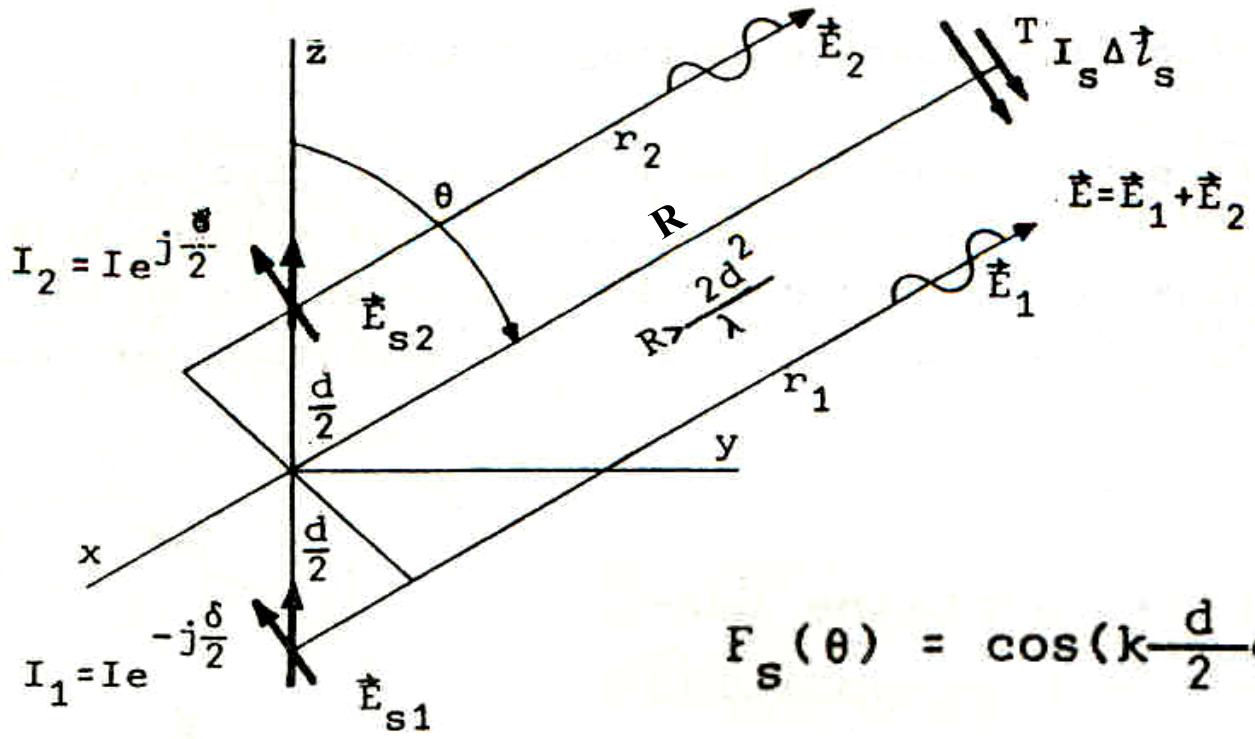
$$E_t = E_1 + E_2 = \hat{a}_\theta j\eta \frac{kI_0 l}{4\pi}\left\{\frac{e^{-j[kr_1-(\beta/2)]}}{r_1}\cos\theta_1 + \frac{e^{-j[kr_2-(\beta/2)]}}{r_2}\cos\theta_2\right\}$$

Skupina dveh elementov



$$E_t = \hat{a}_\theta j\eta \frac{kI_0 l e^{-jkr}}{4\pi r} \cos\theta \cdot 2\cos\left[\frac{1}{2}(kd\cos\theta + \beta)\right]$$

Dvoelementna skupina elementarnih dipolov



$$F_s(\theta) = \cos\left(k\frac{d}{2}\cos\theta + \frac{\delta}{2}\right)$$

$$\vec{E}(T)\,\vec{1}_\theta I_s \Delta l_s = E(T) I_s \Delta l_s = \vec{E}_{s1}\,\vec{1}_z I_1 \Delta l + \vec{E}_{s2}\,\vec{1}_z I_2 \Delta l.$$

$$\vec{E}(T) = \vec{1}_\theta jZ_o \frac{I\Delta l}{2\lambda} \frac{e^{-jkR}}{R} \sin\theta\; 2\cos\left(k\frac{d}{2}\cos\theta + \frac{\delta}{2}\right).$$

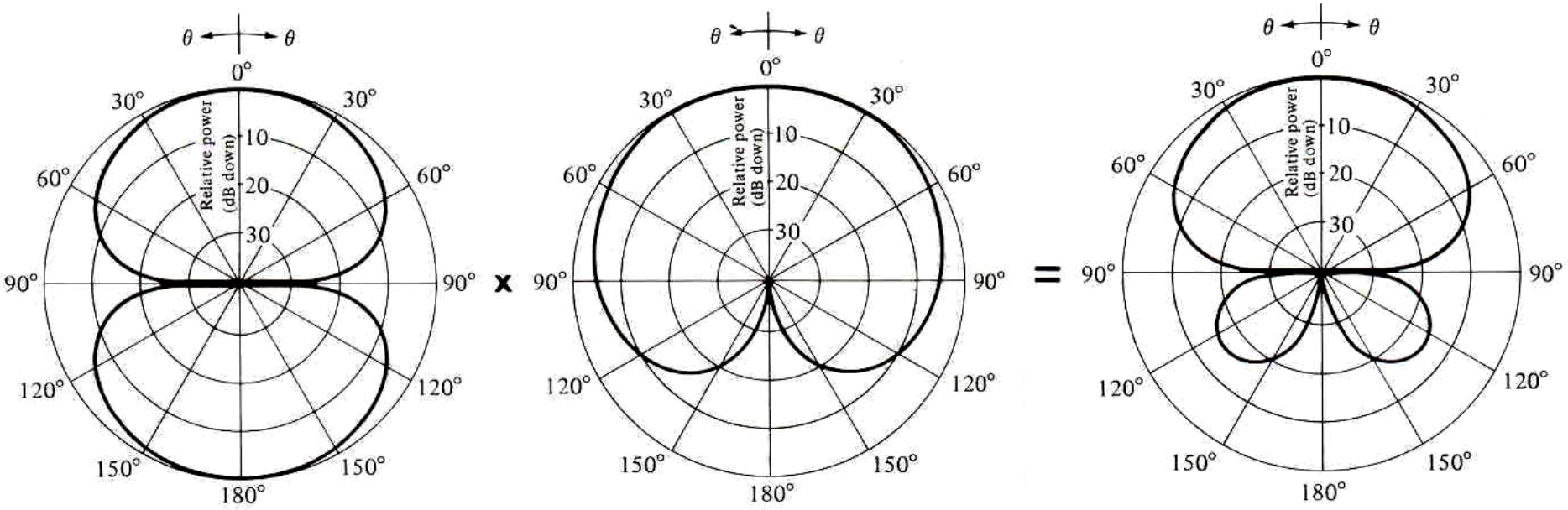
$$F(\theta) = \sin\theta \cos\left(k\frac{d}{2}\cos\theta + \frac{\delta}{2}\right)$$

Skupina dveh elementarnih dipolov v smeri osi y

Podatki:

- Enaki amplitudi
- Fazna razlika -90^0
- Razdalja $\lambda/4$

Iz primera je razvidno, da lahko z dvoelementno skupino oblikujemo smerni diagram na različne načine, če primerno izberemo fazno razliko pri enakih amplitudah.



Elementarni dipol | Skupina izotropnih virov | Skupina elementarnih dipolov

Faktorizacija diagramov

Vrste antenskih skupin:

- Enodimenzionalna (linearna, prema) skupina anten (virov)
- Dvodimenzionalna (ploskovna, ravninska) skupina anten (virov)
- Trodimenzionalna (prostorska) skupina anten (virov)

Izrek o faktorizaciji: Smerni diagram $F(\theta,\phi)$ skupine usmerjenih virov je produkt smernega diagrama vira $F_v(\theta,\phi)$ in smernega diagrama skupine izotropnih virov $F_s(\theta,\phi)$:

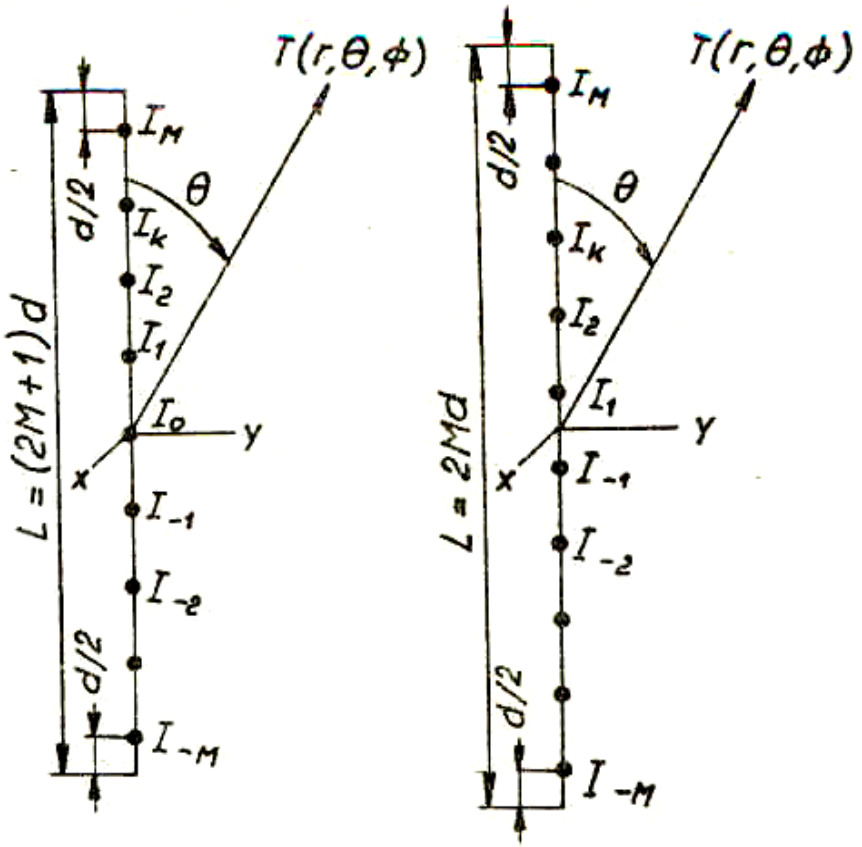
$$F(\theta,\phi) = F_v(\theta,\phi)\, F_s(\theta,\phi)$$

$F(\theta,\phi) = F_v(\theta,\phi)\, F_s(\theta,\phi)$; absolutna vrednost

$\mathrm{Arg}(F(\theta,\phi) = \mathrm{Arg}(F_v(\theta,\phi) + \mathrm{Arg}(F_s(\theta,\phi)$; faza

Ekvidistantna linearna in planarna skupina

Prema skupina izotropnih virov

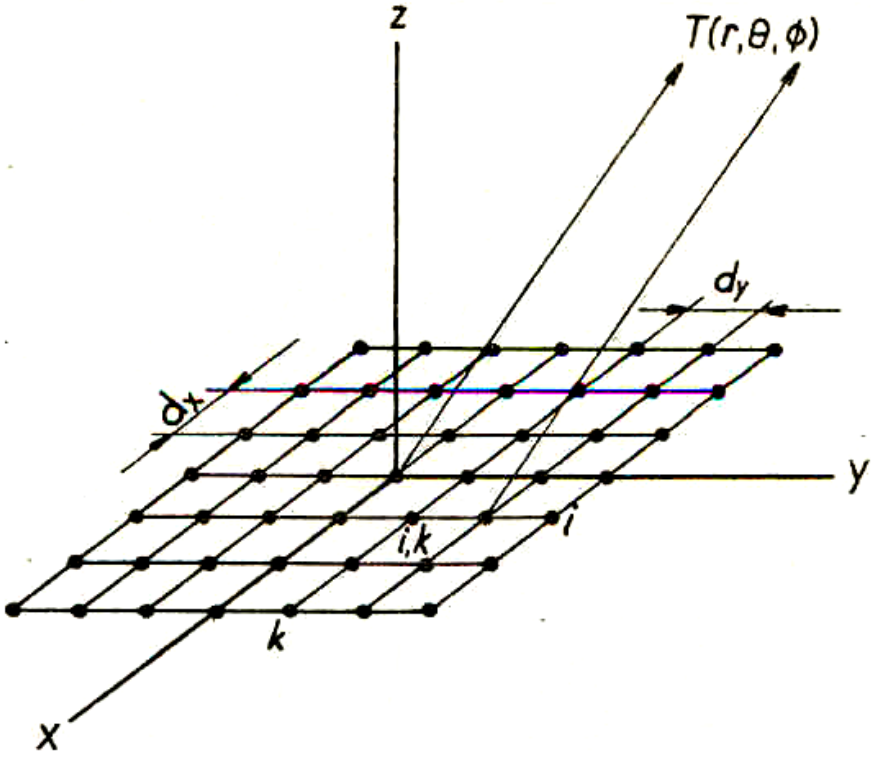


d ekvidistantna razdalja v smeri z med 2M+1 viri

$I_m = |I_m| \exp(j\delta_m)$, tok,

m = -M,...0,...M

Ravninska skupina izotropnih virov

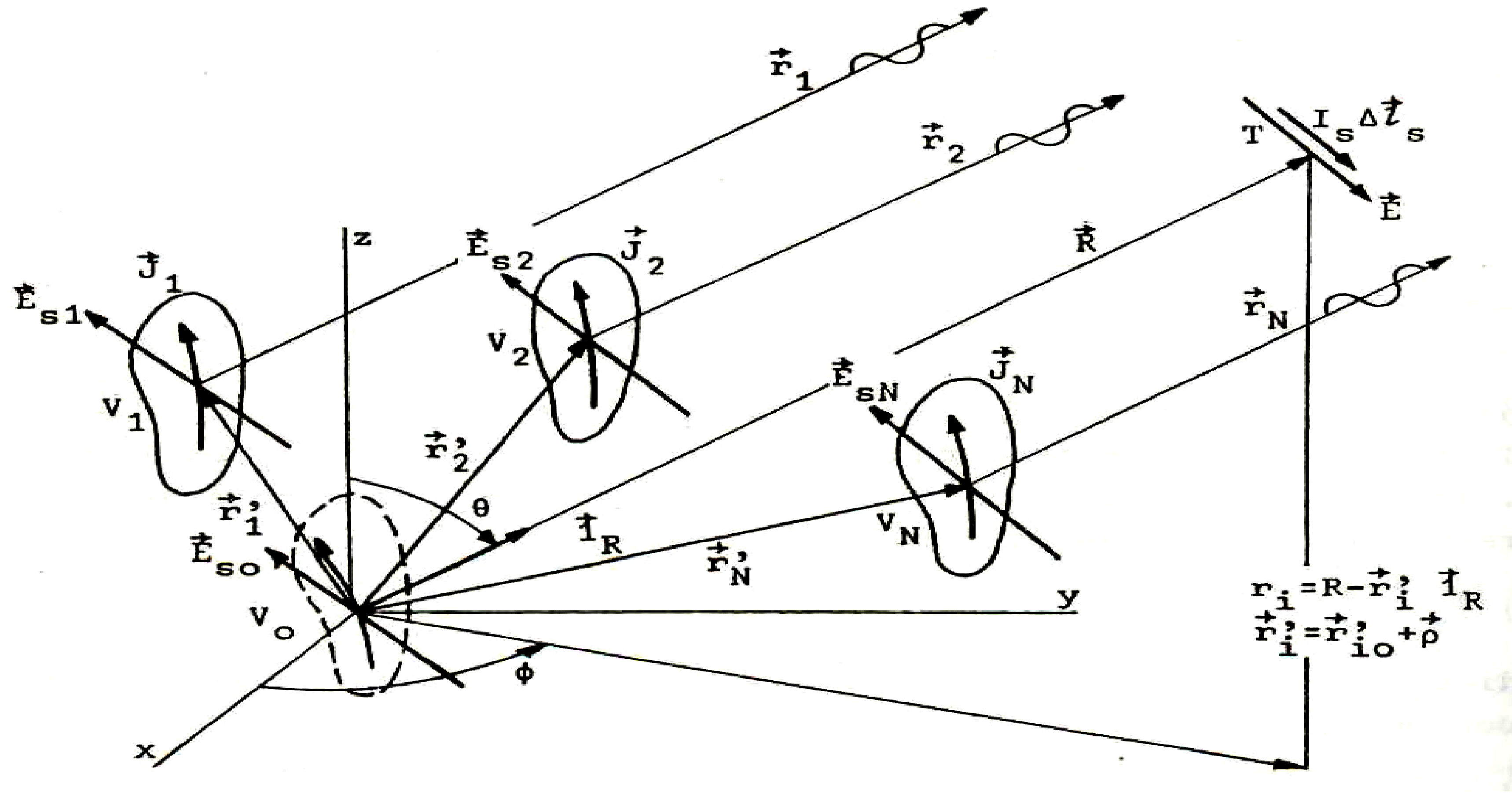


d_x, d_y ekvidistantna razdalja v smereh x in y med (2M+1)×(2N+1) viri

$I_{m,n}=|Im,n| \exp(j\delta m) \exp(j\delta_n)$, tok,

m= -M,...0,...M; n = -N,...0,...N;

Peostorska skupina anten



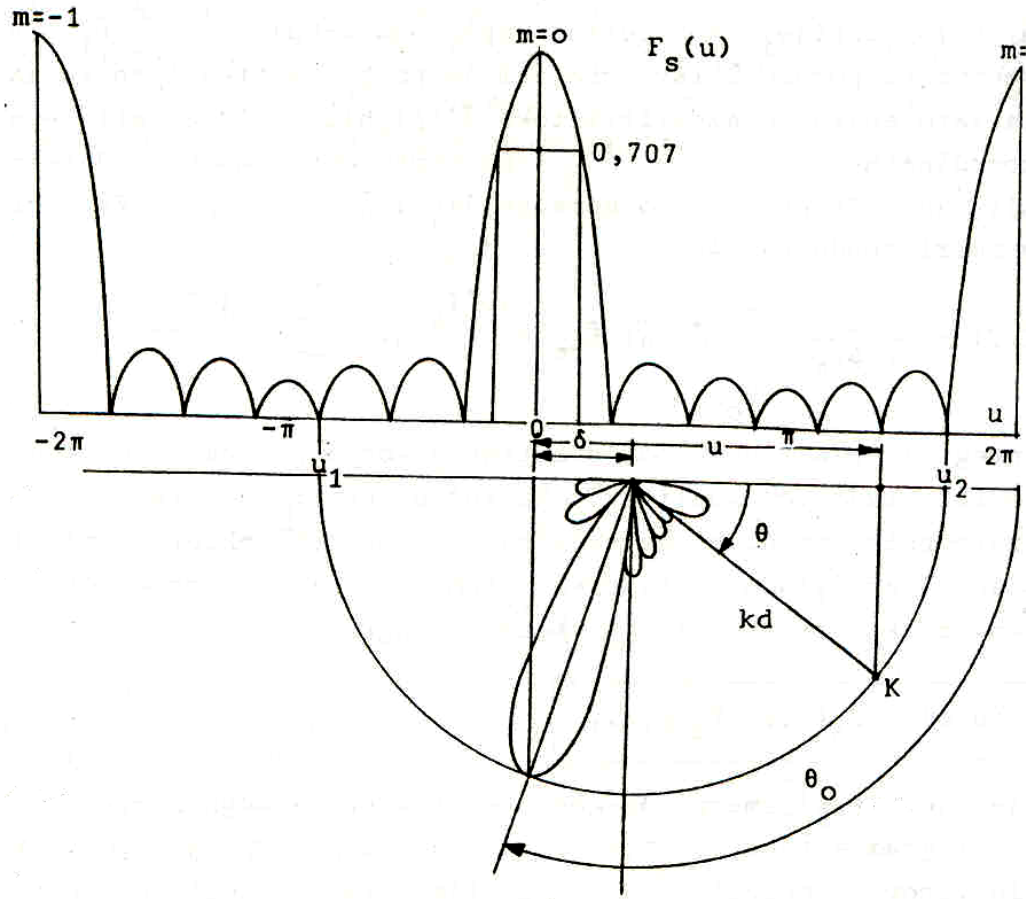
Prostorsko skupino anten nadomestimo z izotropnimi viri:

- Namestimo jih v fazna središča anten v skupini (točka navideznega izhajanja vala)
- Vzbujamo jih z enako amplitudo in fazo kot resnične antene.

Normirani smerni diagram ekvidistantne preme skupine s konstantnim vzbujanjem amplitude

Podatki:

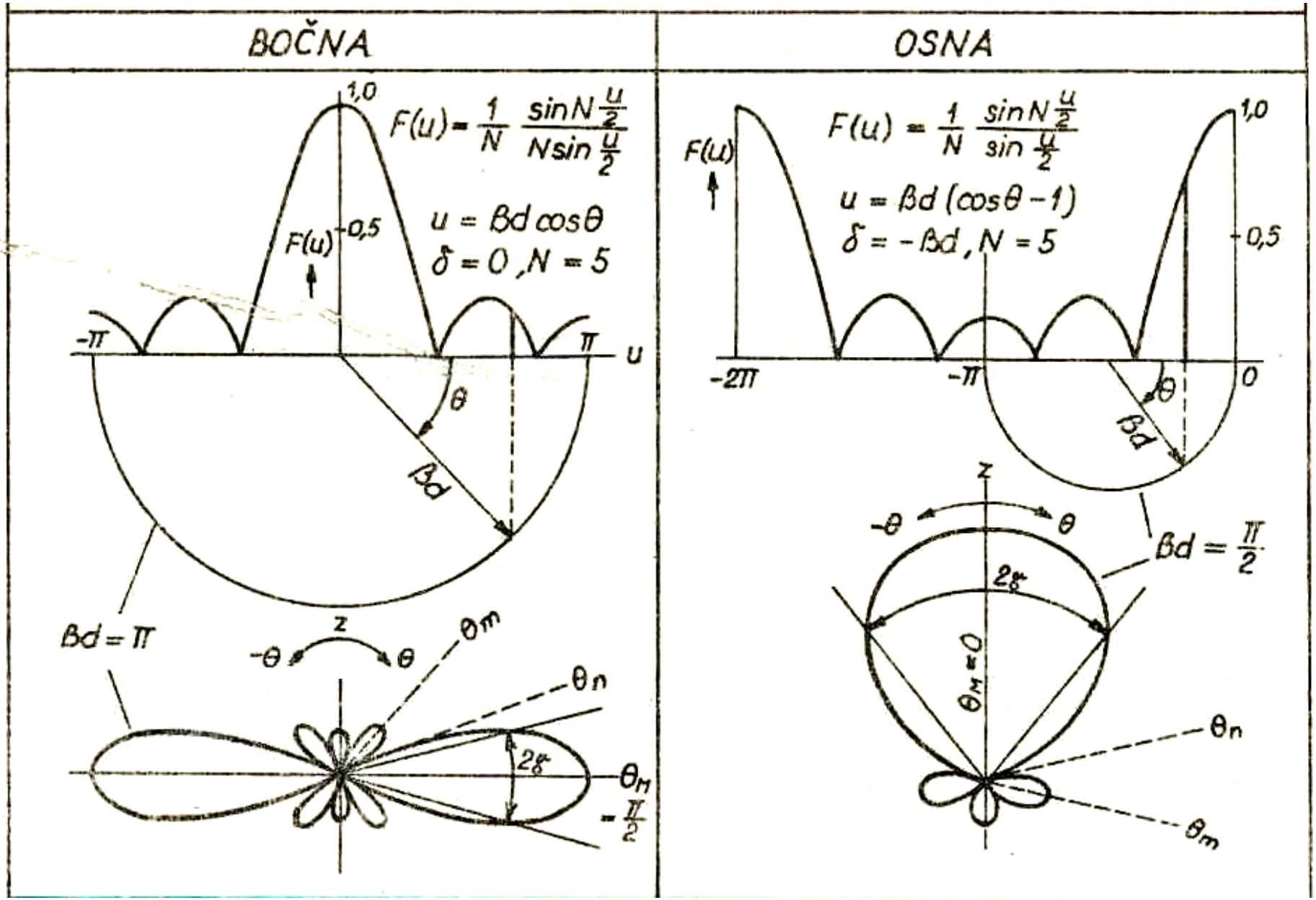
- Enake amplitude
- Enaka faza razlika δ
- Enaka razdalja d
- Število elementov N
- Smer glavnega snopa $\theta_{max} = 0°$



$$F_s(u) = \frac{1}{N} e^{-j\frac{N}{2}u} \frac{1-e^{jNu}}{1-e^{ju}} = \frac{1}{N} \frac{\sin\frac{N}{2}u}{\sin\frac{1}{2}u} =$$

$$= \frac{1}{N} \frac{\sin\left(\frac{N}{2}(kd\cos\theta+\delta)\right)}{\sin\left(\frac{1}{2}(kd\cos\theta+\delta)\right)} = \frac{1}{N} \frac{\sin\left(\frac{N}{2}kd(\cos\theta-\cos\theta_o)\right)}{\sin\left(\frac{1}{2}kd(\cos\theta-\cos\theta_o)\right)}$$

Bočna in osna skupina 1/4



Bočna in osna skupina 2/4

Lega glavnega snopa	
$\theta_m = \frac{\pi}{2}$, $\frac{d}{\lambda} < 1$	$\theta_m = 0$, $\frac{d}{\lambda} < \frac{1}{2}$
Širina glavnega snopa	
$2\gamma = \arccos(-0{,}443\frac{\lambda}{L}) - \arccos(0{,}443\frac{\lambda}{L})$ $2\gamma \doteq 0{,}886\frac{\lambda}{L}$, $L > 5\lambda$	$2\gamma = 2\arccos(1 - 0{,}443\frac{\lambda}{L})$ $2\gamma \doteq 2\sqrt{0{,}886\frac{\lambda}{L}}$, $L > 5\lambda$
Lega ničel	
$\theta_n = \arccos\frac{n2\pi}{N\beta d}$, $n = \pm 1, \pm 2 \ldots$ $\lvert n\rvert \leq \frac{N\beta d}{2\pi}$ $\frac{\pi}{2} - \theta_n = \arcsin\frac{n2\pi}{N\beta d} \doteq \frac{n\lambda}{Nd}$	$\theta_n = \arccos(1 + \frac{n2\pi}{N\beta d})$, $n = -1, -2 \ldots$ $\lvert n\rvert < \frac{N\beta d}{\pi}$ $\theta_n = 2\arcsin(\pm\sqrt{\frac{\lvert n\rvert\pi}{N\beta d}}) \doteq \pm 2\sqrt{\frac{\lvert n\rvert\pi}{N\beta d}}$
Kot med prvima ničlama	
$2\gamma_n = 2\arcsin\frac{2\pi}{N\beta d}$ $2\gamma_n \doteq \frac{4\pi}{N\beta d} = \frac{2\lambda}{Nd}$	$2\gamma_n = 4\arcsin\sqrt{\frac{\pi}{N\beta d}}$ $2\gamma_n \doteq 4\sqrt{\frac{\pi}{N\beta d}} = 2\sqrt{\frac{2\lambda}{Nd}}$

Bočna in osna skupina 3/4

Bočna	Osna
Lega stranskih snopov	
$\theta_m = \arccos\left(\pm \frac{2m+1}{N\beta d}\pi\right),\ m = 1,2,\ldots$ $m < \frac{N\beta d}{2\pi} - \frac{1}{2}$ $\frac{\pi}{2} - \theta_m \doteq \pm\left(m+\frac{1}{2}\right)\frac{\lambda}{Nd}$	$\theta_m = \arccos\left(-\frac{(2m+1)\pi}{N\beta d}+1\right),\ m = 1,2,\ldots$ $m < \frac{N\beta d}{\pi} - \frac{1}{2}$ $\theta_m = 2\arcsin\left(\pm\sqrt{\frac{(m+\frac{1}{2})\pi}{N\beta d}}\right) \doteq \pm 2\sqrt{\frac{(m+\frac{1}{2})\pi}{N\beta d}}$
Velikost stranskih snopov	
$F(\theta_m) = \frac{(-1)^m}{\sqrt{1+(N^2-1)\sin^2\frac{u_m}{2}}}, \quad u_m = \beta d\cos\theta_m + \delta$	
Smernost	
$D = \frac{N}{1+\sum_{k=1}^{N-1} 2\left(1-\frac{k}{N}\right)\frac{\sin k\beta d}{k\beta d}}$	$D = \frac{N}{1+\sum_{k=1}^{N-1} 2\left(1-\frac{k}{N}\right)\frac{\sin 2k\beta d}{2k\beta d}}$

Bočna in osna skupina 4/4

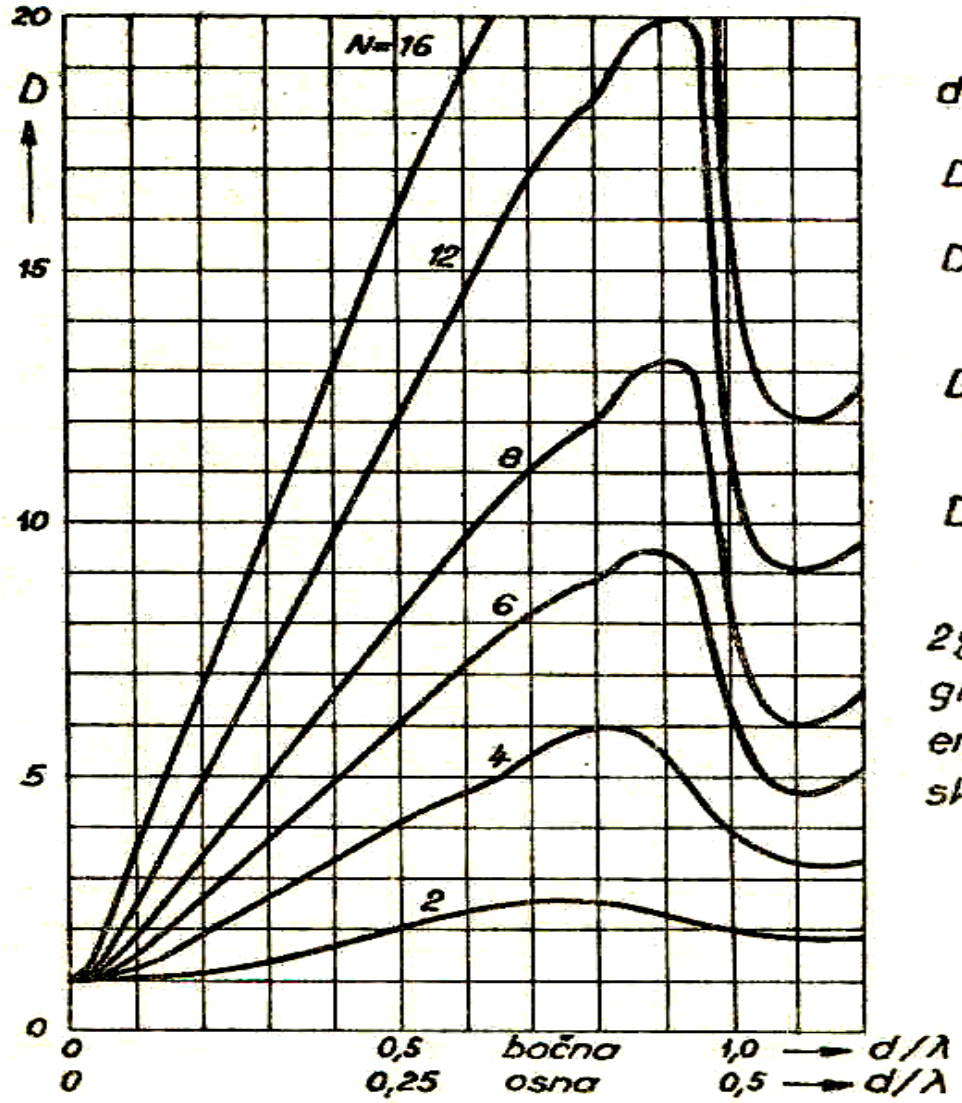
$d = \frac{\lambda}{2}, \lambda$

$D = N$

$D = \frac{2L}{\lambda}$

$D = \frac{1,77}{2\vartheta\,[rad]}$

$D = \frac{101,5}{2\vartheta\,[°]}$



$d = \frac{\lambda}{2}, \lambda$

$D = N$

$D = \frac{2L}{\lambda}$

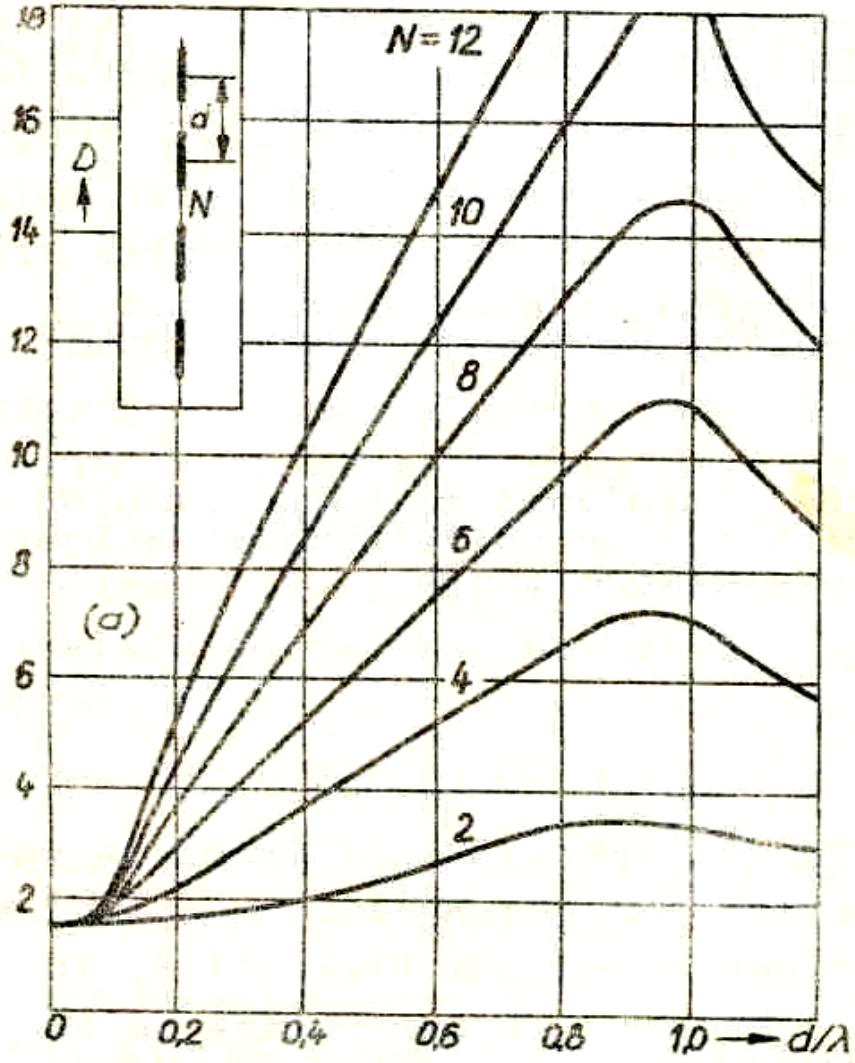
$D = \frac{1,77}{2\vartheta\,[rad]}$

$D = \frac{101,5}{2\vartheta\,[°]}$

2ϑ je širina glavnega snopa enake boč- skupi-.

Smernost bočne skupine elementarnih dipolov

Dipolska vrstica



Dipolska lestvica

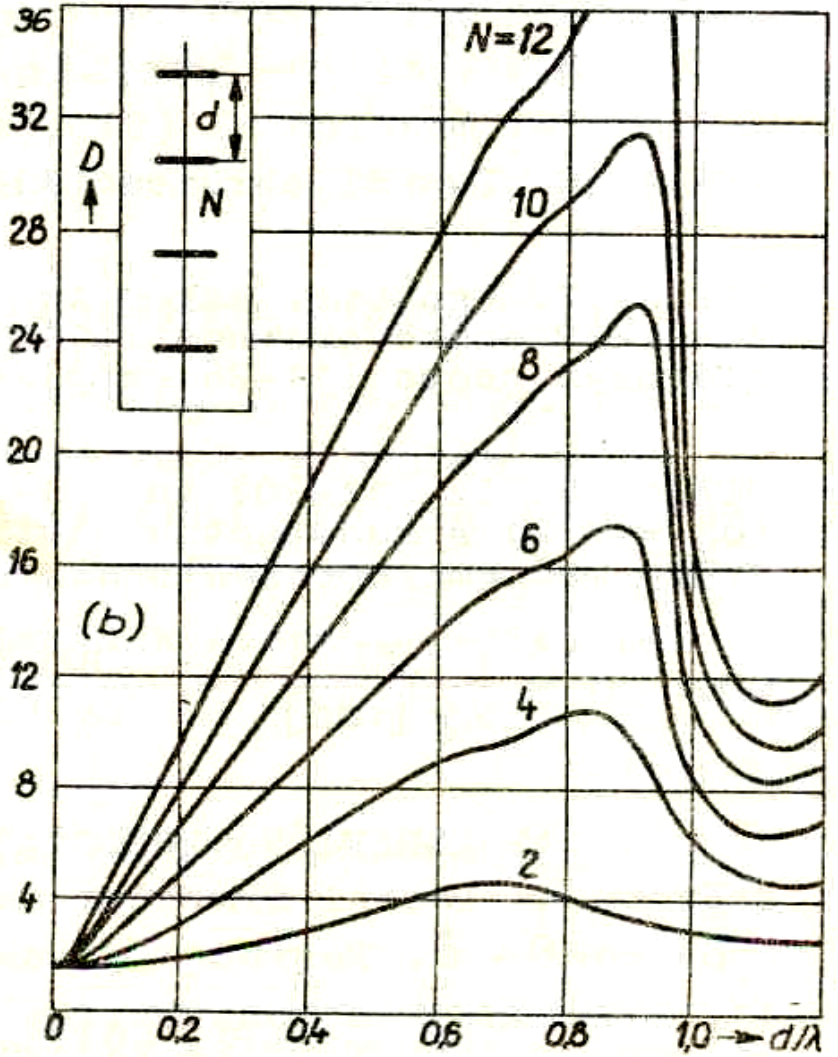
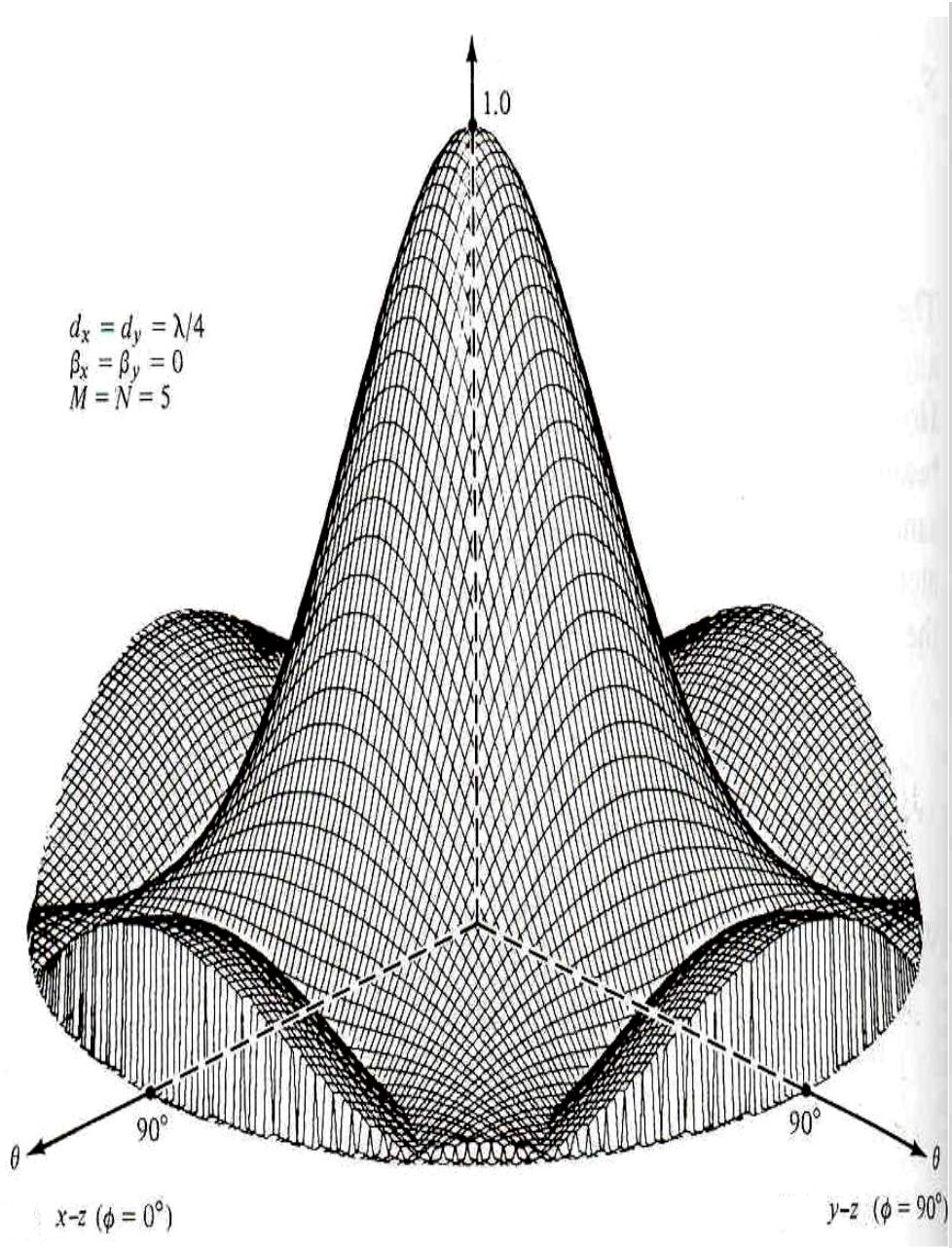
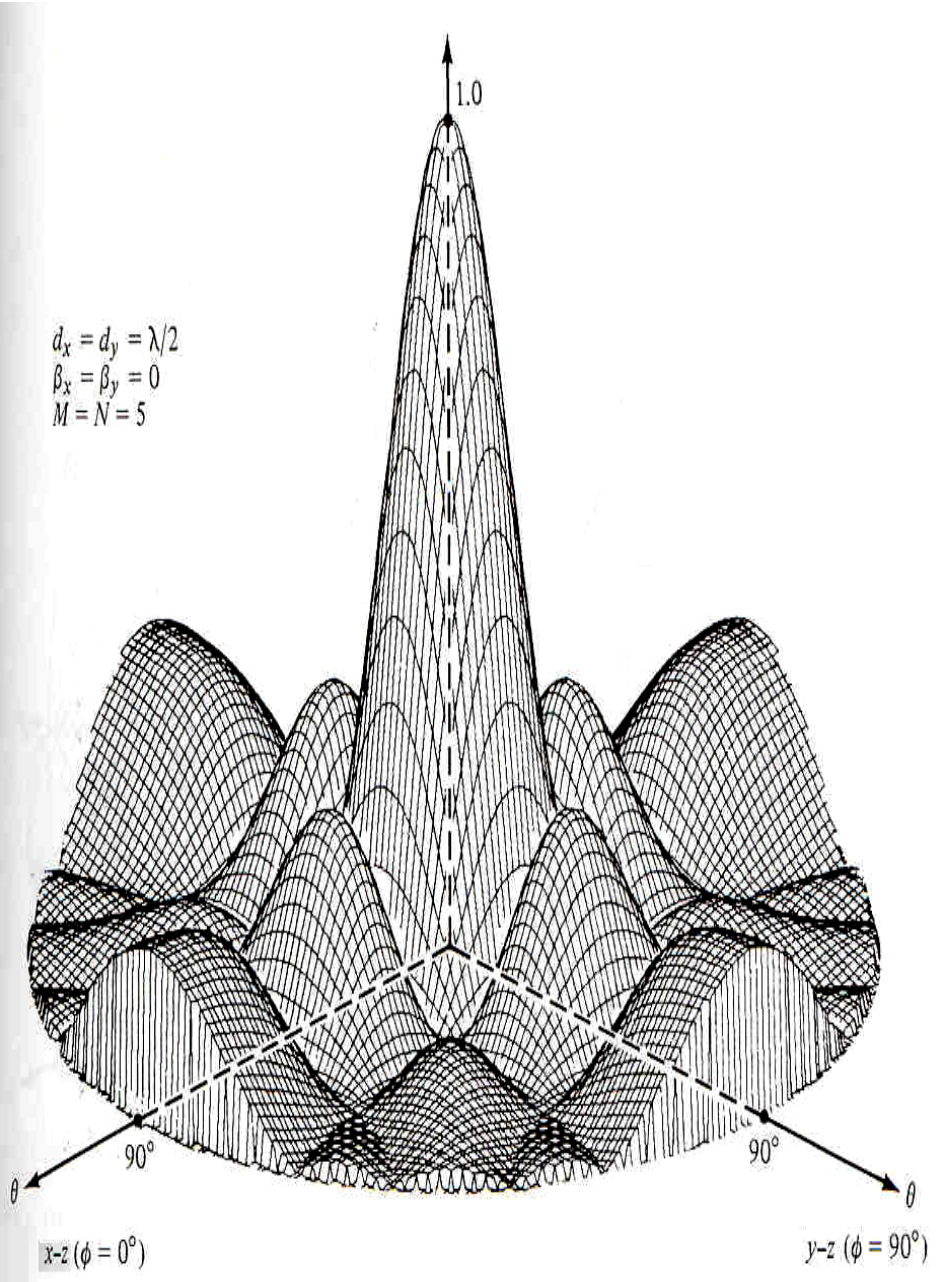


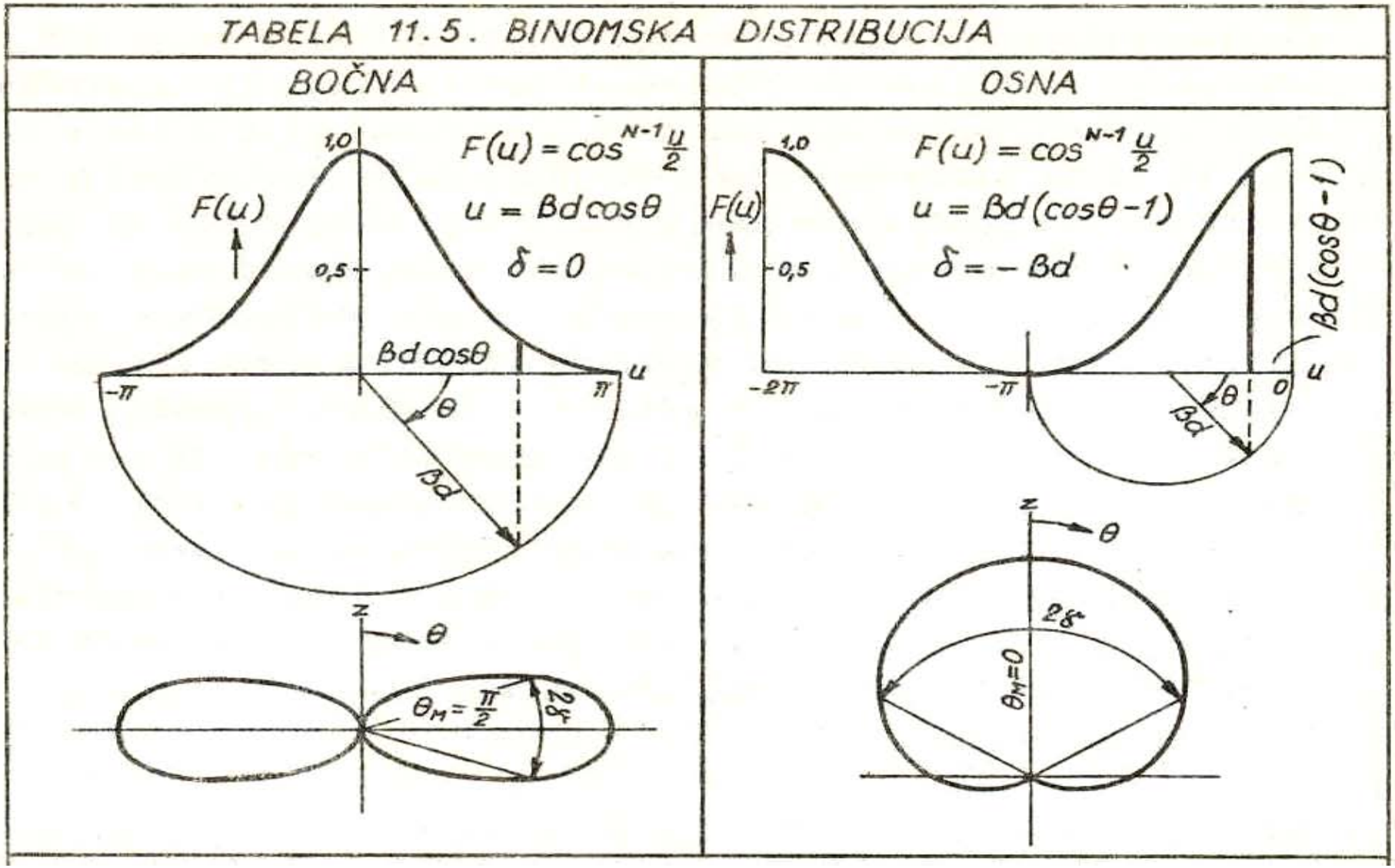
Diagram sofazne bočne skupine





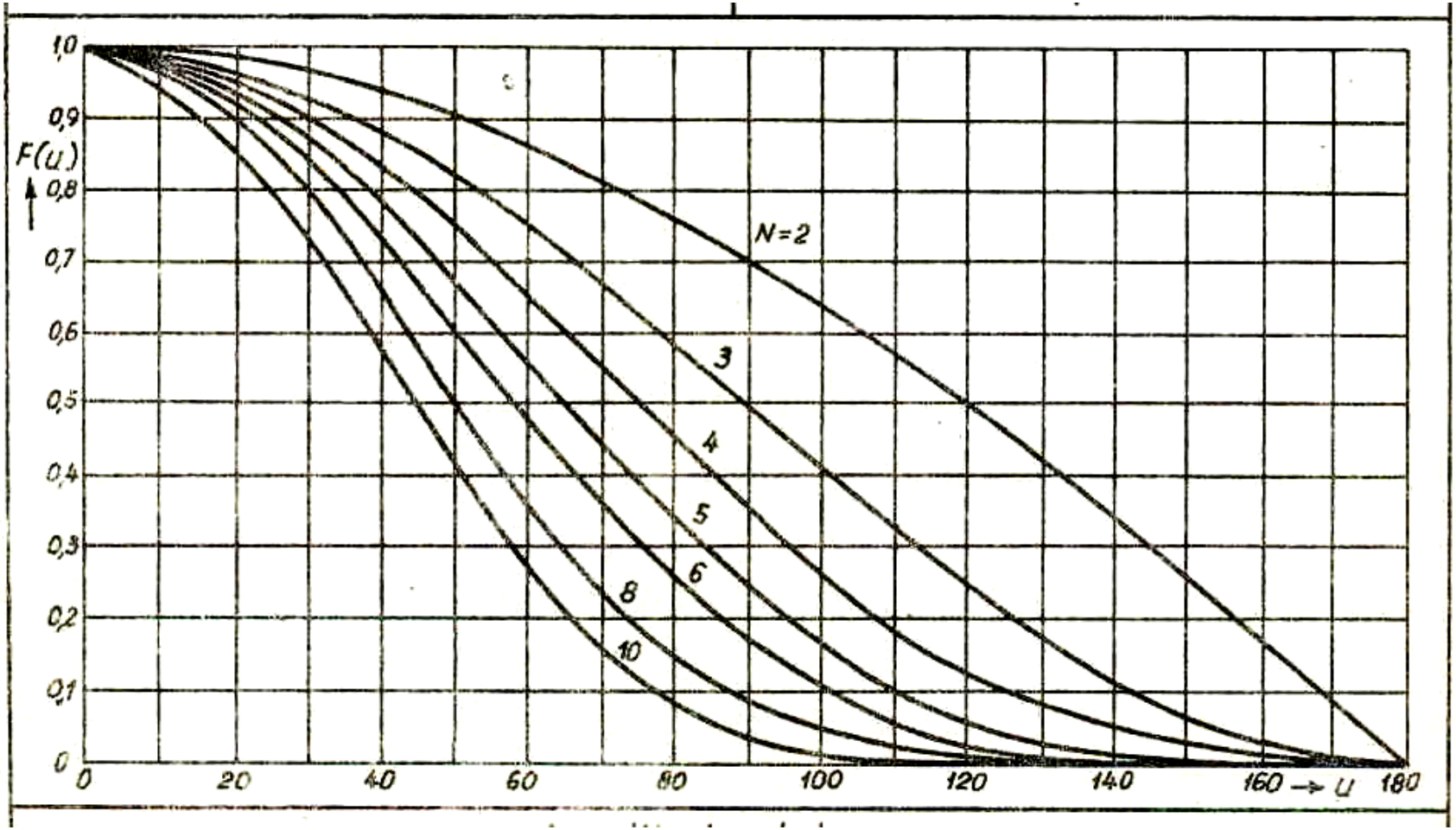
Binomska skupina izotropnih virov 1/2

Primer upadajoče distribucije po binomskih koeficientih (diskretna analogija zvezne Gaussove distribucije)



Binomska skupina izotropnih virov 2/2

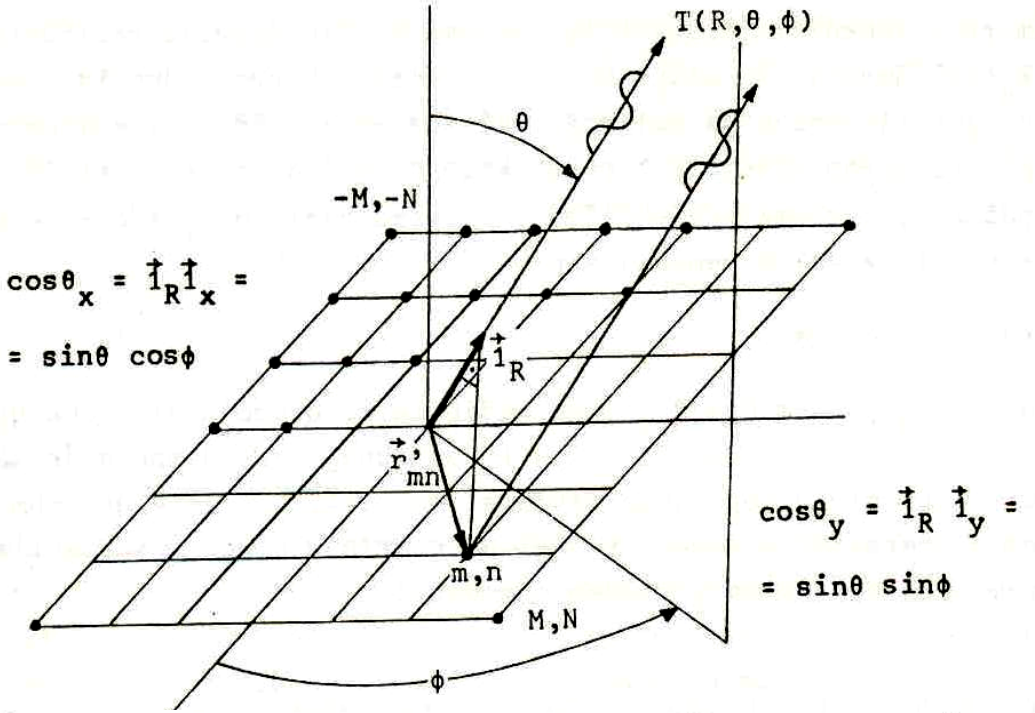
Smerni diagram



Normirani smerni diagram ravninske skupine s konstantnim vzbujanjem 1/2

Podatki:

- Enake amplitude
- Število elementov M, N
- Fazna razlika δ_x, δ_y
- Razdalja d_x, d_y



Smer glavnega snopa:

$$\cos\theta_{xo} = -\delta_x/kd_x \text{ in } \cos\theta_{yo} = -\delta_y/kd_y$$

Smerni diagram:

$$F_s(\theta,\phi) = F_m(\theta,\phi)F_n(\theta,\phi) = \sum_{m=-M}^{M}|A_m|e^{jmu}\sum_{n=-N}^{N}|A_n|e^{jnv} \qquad F_s(u,v) = \frac{1}{MN}\frac{\sin\frac{M}{2}u}{\sin\frac{1}{2}u}\frac{\sin\frac{N}{2}v}{\sin\frac{1}{2}v}$$

$$F_s(\theta,\phi) = \frac{1}{MN}\frac{\sin(\frac{M}{2}kd_x\cos\theta_x - \cos\theta_{xo}))}{\sin(\frac{1}{2}kd_x(\cos\theta_x - \cos\theta_{xo}))}\frac{\sin(\frac{N}{2}kd_y(\cos\theta_y - \cos\theta_{yo}))}{\sin(\frac{1}{2}kd_y(\cos\theta_y - \cos\theta_{yo}))}$$

Ravninska skupina 1/4

TABELA 11.6. PLOSKOVNA SKUPINA

$$F(\theta,\Phi) = F_x(\theta,\Phi) \cdot F_y(\theta,\Phi)$$

$$N_x = 2M_x + 1$$

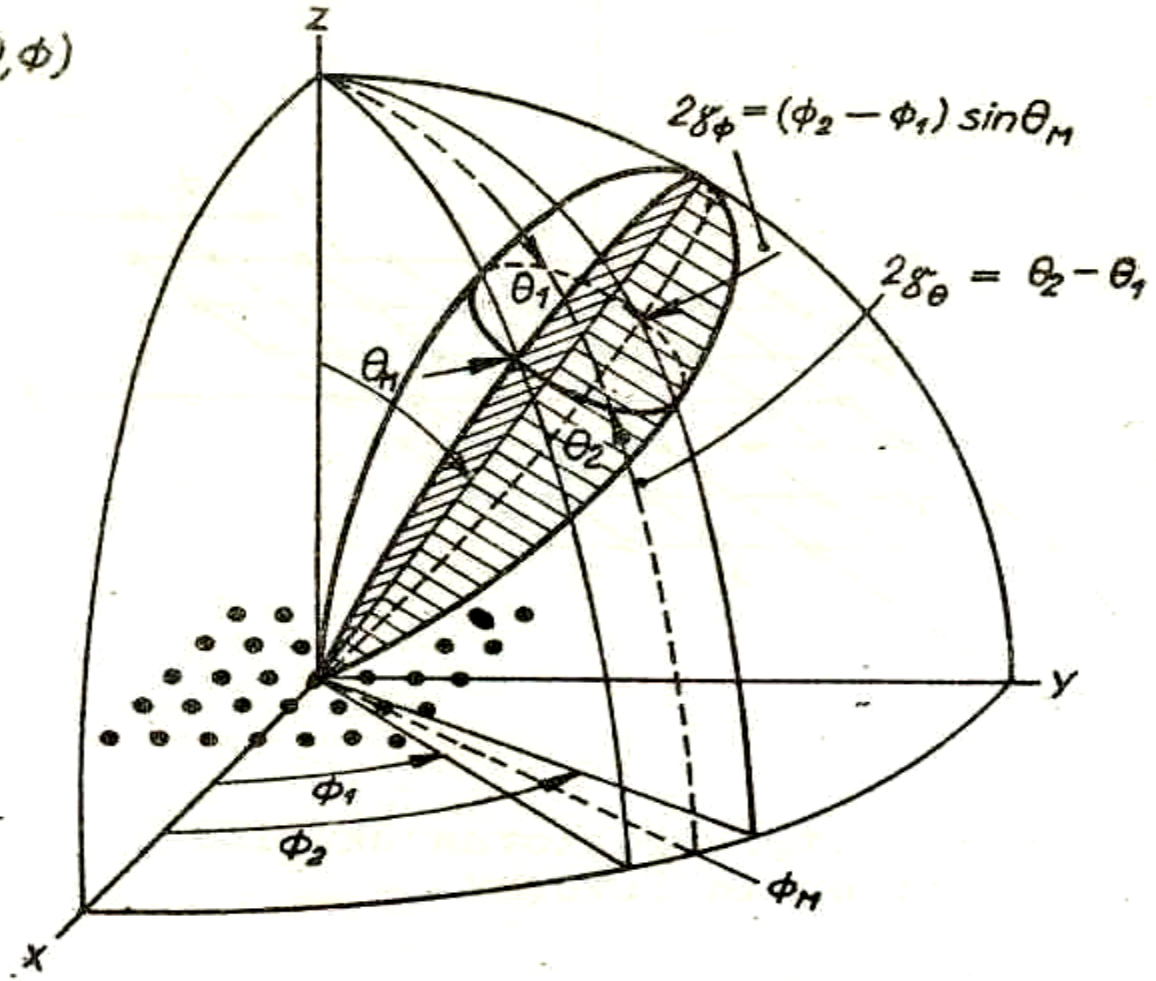
$$N_y = 2M_y + 1$$

$$L_x = N_x d_x$$

$$L_y = N_y d_y$$

Kriterij za obstoj glavnega snopa

$$\frac{\delta_x^2}{\beta^2 d_x^2} + \frac{\delta_y^2}{\beta^2 d_y^2} \leq 1$$



Ravninska skupina 2/4

Simetrična distribucija	Konstantna distribucija
Sevalni diagram	
$F_x = \dfrac{\sum_{-M_x}^{M_x} \lvert I_i \rvert e^{ji(\beta d_x \sin\theta\cos\phi + \delta_x)}}{\sum_{-M_x}^{M_x} \lvert I_k \rvert}$ (1-a)	$F_x = \frac{1}{N_x} \dfrac{\sin\left[\frac{N_x}{2}(\beta d_x \sin\theta\cos\phi + \delta_x)\right]}{\sin\left[\frac{1}{2}(\beta d_x \sin\theta\cos\phi + \delta_x)\right]}$ (2-a)
$F_y = \dfrac{\sum_{-M_y}^{M_y} \lvert I_k \rvert e^{jk(\beta d_y \sin\theta\sin\phi + \delta_y)}}{\sum_{-M_y}^{M_y} \lvert I_k \rvert}$ (1-b)	$F_y = \frac{1}{N_y} \dfrac{\sin\left[\frac{N_y}{2}(\beta d_y \sin\theta\sin\phi + \delta_y)\right]}{\sin\left[\frac{1}{2}(\beta d_y \sin\theta\sin\phi + \delta_y)\right]}$ (2-b)
Lega glavnega snopa	
$tg\,\phi_M = -\dfrac{\delta_y d_x}{\delta_x d_y}$ (3-a)	$\sin^2\theta_M = \dfrac{\delta_x^2}{\beta^2 d_x} + \dfrac{\delta_y^2}{\beta^2 d_y}$ (3-b)

Ravninska skupina 3/4

IZOTROPNIH IZVOROV

Simetrična distribucija	Konstantna distribucija

Širina glavnega snopa bočne in splošne skupine ($\theta_M < \frac{\pi}{2}$)

$L_x \gg \lambda$, $L_y \gg \lambda$

$$2\gamma_\theta = \frac{2\gamma_{yo}}{\cos\theta_M \left(\sin^2\phi_M + \left(\frac{2\gamma_{yo}}{2\gamma_{xo}}\right)^2 \cos\phi_M\right)^{\frac{1}{2}}} \qquad (4\text{-}a)$$

$$2\gamma_\phi = \frac{2\gamma_{xo}}{\left(\sin^2\phi_M + \left(\frac{2\gamma_{xo}}{2\gamma_{yo}}\right)^2 \cos^2\phi_M\right)^{\frac{1}{2}}} \qquad (4\text{-}b)$$

$2\gamma_{xo}$ ($2\gamma_{yo}$) širina glavnega snopa sofazno vzbujanega stolpca (vrstice)

$L_x \gg \lambda$, $L_y \gg \lambda$

$$2\gamma_\theta = \frac{0{,}886\,\frac{\lambda}{L_y}}{\cos\theta_M \left(\sin^2\phi_M + \left(\frac{L_x}{L_y}\right)^2 \cos\phi_M\right)^{\frac{1}{2}}} \qquad (5\text{-}a)$$

$$2\gamma_\phi = \frac{0{,}886\,\frac{\lambda}{L_x}}{\left(\sin^2\phi_M + \left(\frac{L_y}{L_x}\right)^2 \cos^2\phi_M\right)^{\frac{1}{2}}} \qquad (5\text{-}b)$$

Ravninska skupina 4/4

Smernost bočne ali osne skupine ($\theta_M < \frac{\pi}{2}$)

$d_x = d_y = \frac{\lambda}{2}$, $F(\theta > \frac{\pi}{2}) = 0$

L_x in $L_y \gg \lambda$

$$D = \pi \cos\theta_M \frac{\frac{2L_x}{\lambda}}{\sum_{p=-P}^{P} \left(\frac{A_p}{A_0}\right)^2} \frac{\frac{2L_y}{\lambda}}{\sum_{q=-Q}^{Q} \left(\frac{B_q}{B_0}\right)^2}$$

$$= \pi D_x D_y \cos\theta_M \qquad (6)$$

Velja približno tudi za $\frac{\lambda}{2} < d_x < \lambda$; $\frac{\lambda}{2} < d_y < \lambda$

$d_x = d_y = \frac{\lambda}{2}$, $F(\theta > \frac{\pi}{2}) = 0$

L_x in $L_y \gg \lambda$

$$D = \frac{4\pi}{\lambda^2} L_x L_y \cos\theta_M \qquad (7\text{-a})$$

$$= \pi N_x N_y \cos\theta_M$$

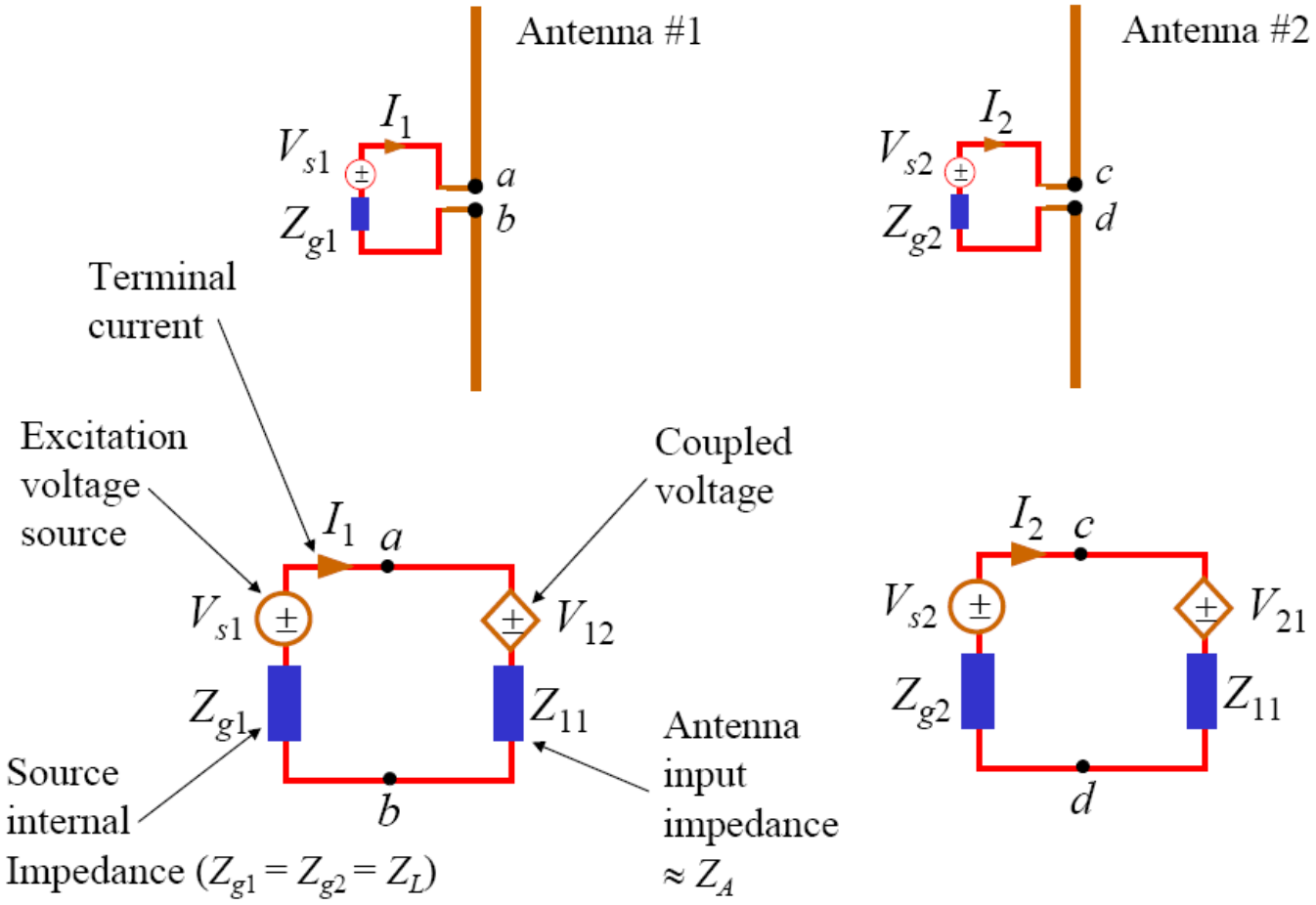
$$A = L_x L_y \cos\theta_M \qquad (7\text{-b})$$

Velja približno tudi za $\frac{\lambda}{2} < d_x < \lambda$; $\frac{\lambda}{2} < d_y < \lambda$

$$D = \frac{9{,}87}{2\delta_\theta \cdot 2\delta_\phi\,[\mathrm{rad}^2]} = \frac{32{,}400}{2\delta_\theta \cdot 2\delta_\phi\,[^{02}]} \qquad (8)$$

$2\delta_\theta$ in $2\delta_\phi$ pri $\phi_M = 0$ ali $\frac{\pi}{2}$

Sklop med dipoloma



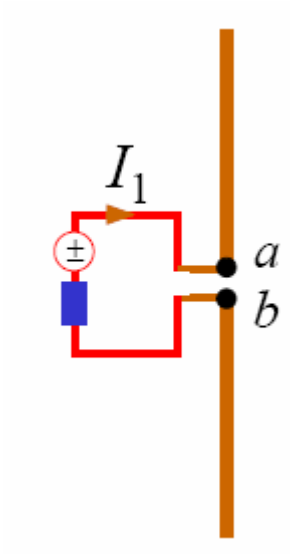
Definicija medsebojne impedance

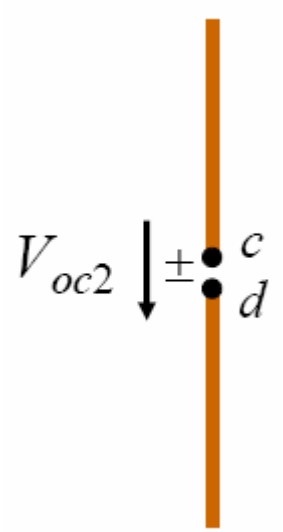
$$Z_{12} = \text{mutual impedance with antenna \#2 excited}$$

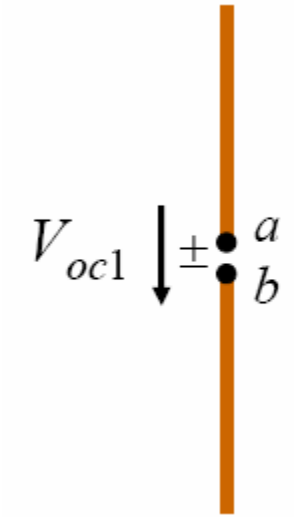
$$= \left.\frac{V_{oc1}}{I_2}\right|_{I_1=0}$$

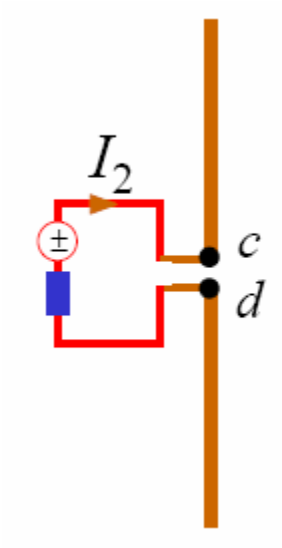
$$= \frac{\text{open - circuit voltage at antenna \#1}}{I_2} = \frac{V_{12}}{I_2}$$

Definicija medsebojne impedance





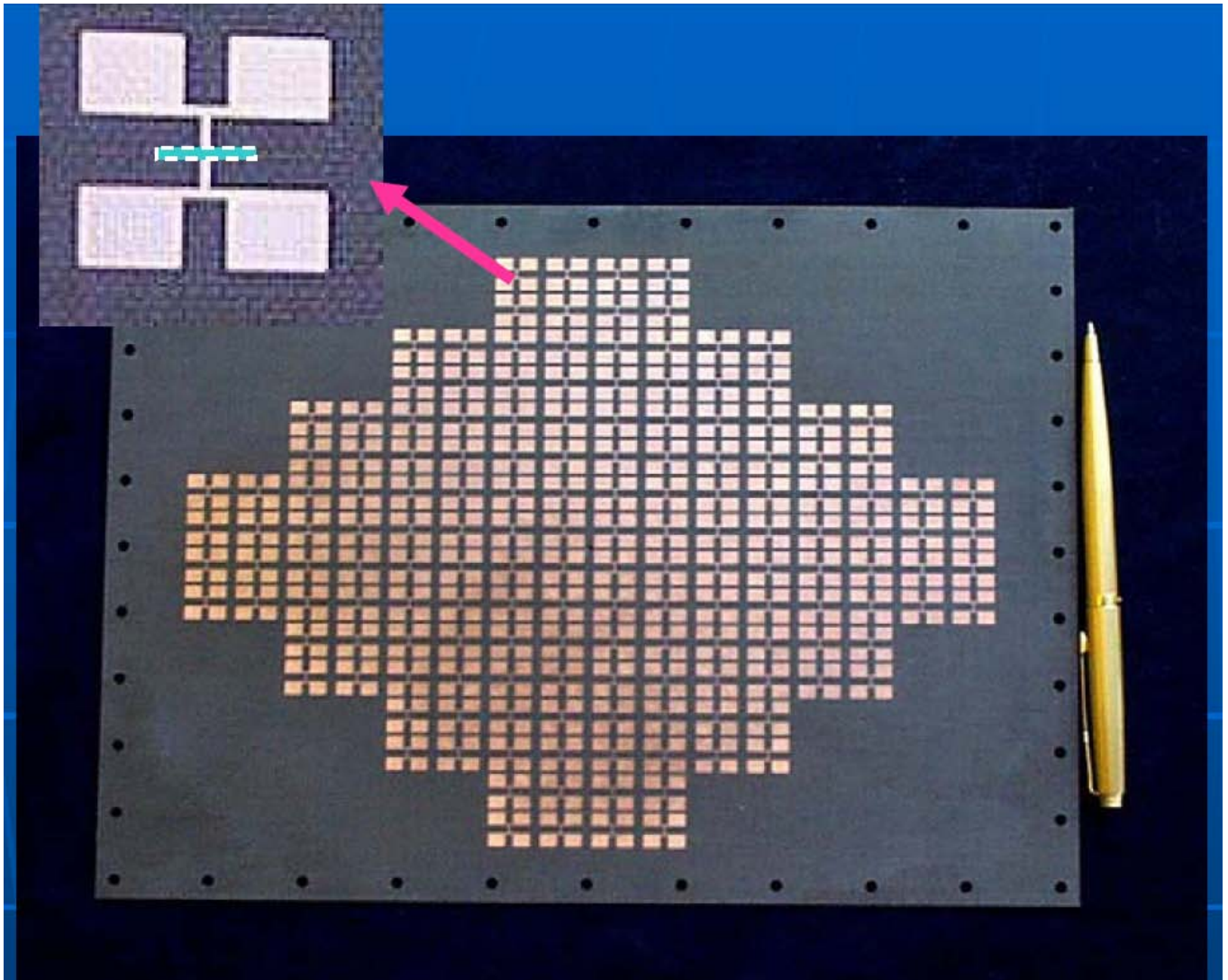


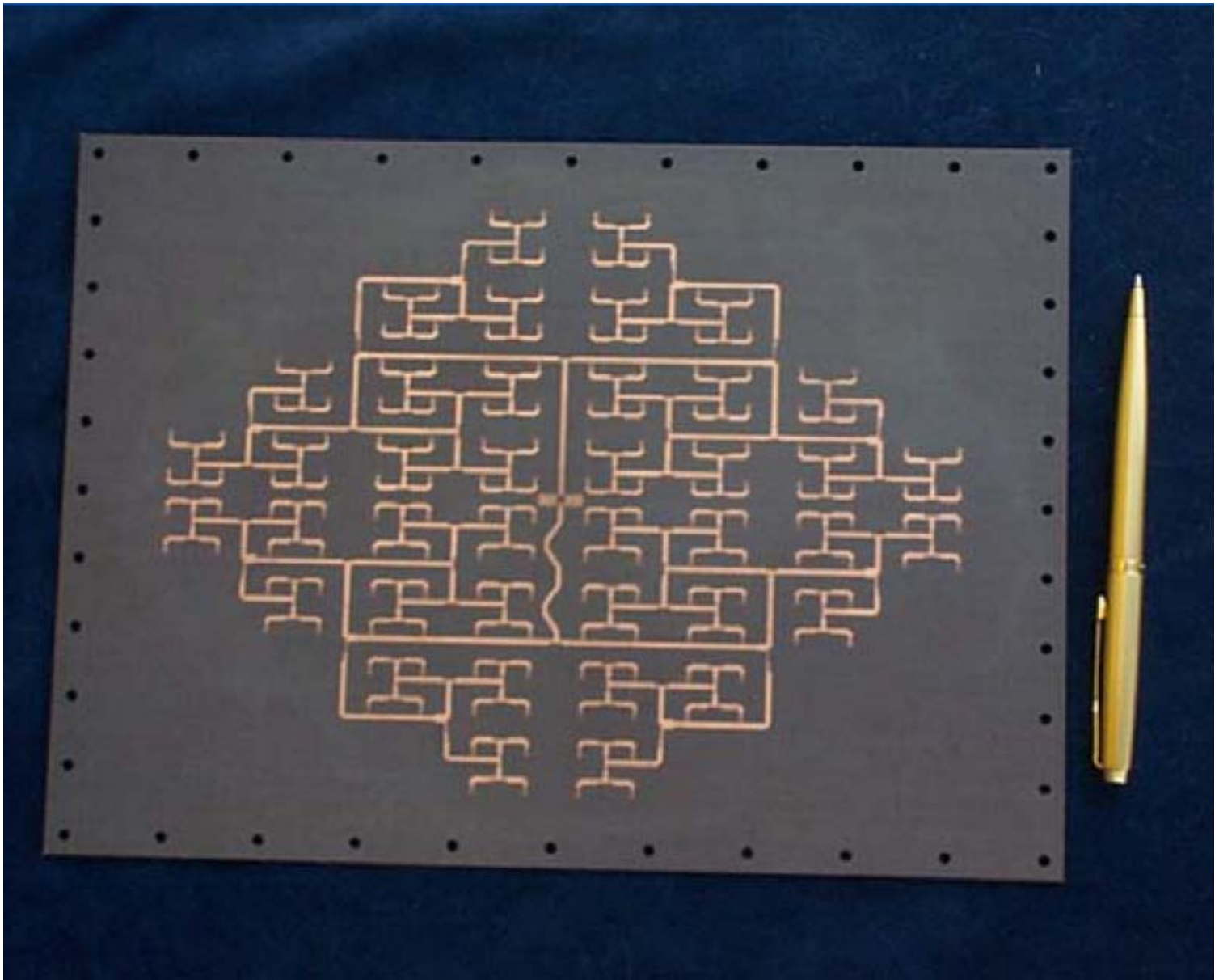


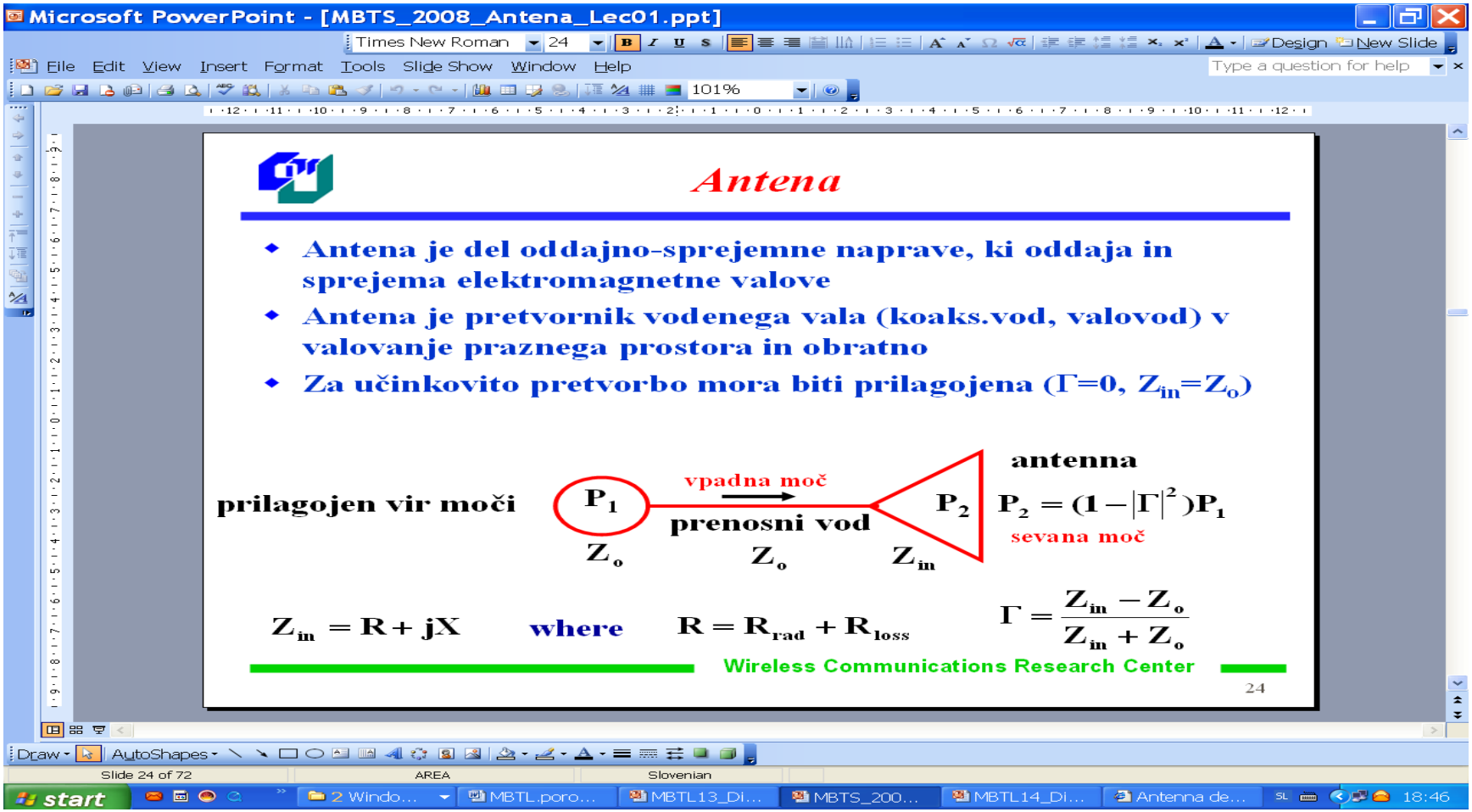
with antenna #1 excited

ge at antenna #2 $= \frac{V_{21}}{I_1}$

V_{oc2} c






Microsoft PowerPoint - [MBTS_2008_Antena_Lec01.ppt]
Antena
Antena je del oddajno-sprejemne naprave, ki oddaja in sprejema elektromagnetne valove
Antena je pretvornik vodenega vala (koaks.vod, valovod) v valovanje praznega prostora in obratno
Za učinkovito pretvorbo mora biti prilagojena (Γ=0, Zin=Zo)
prilagojen vir moči
P1
Zo
vpadna moč
prenosni vod
Zo
P2
Zin
antenna
P2 = (1 − |Γ|²)P1
sevana moč
Zin = R + jX
where
R = Rrad + Rloss
Γ = (Zin − Zo)/(Zin + Zo)
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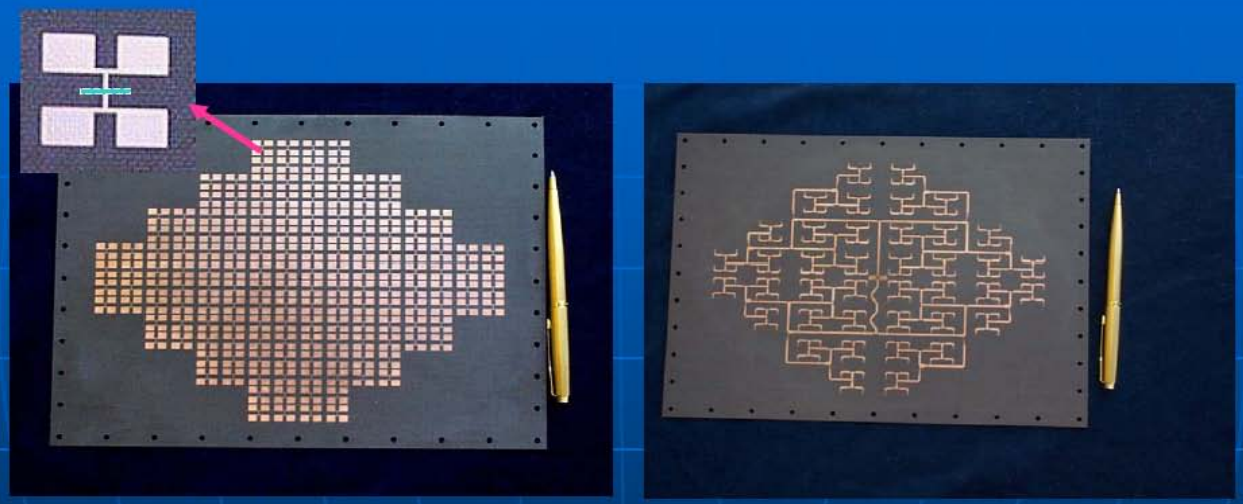

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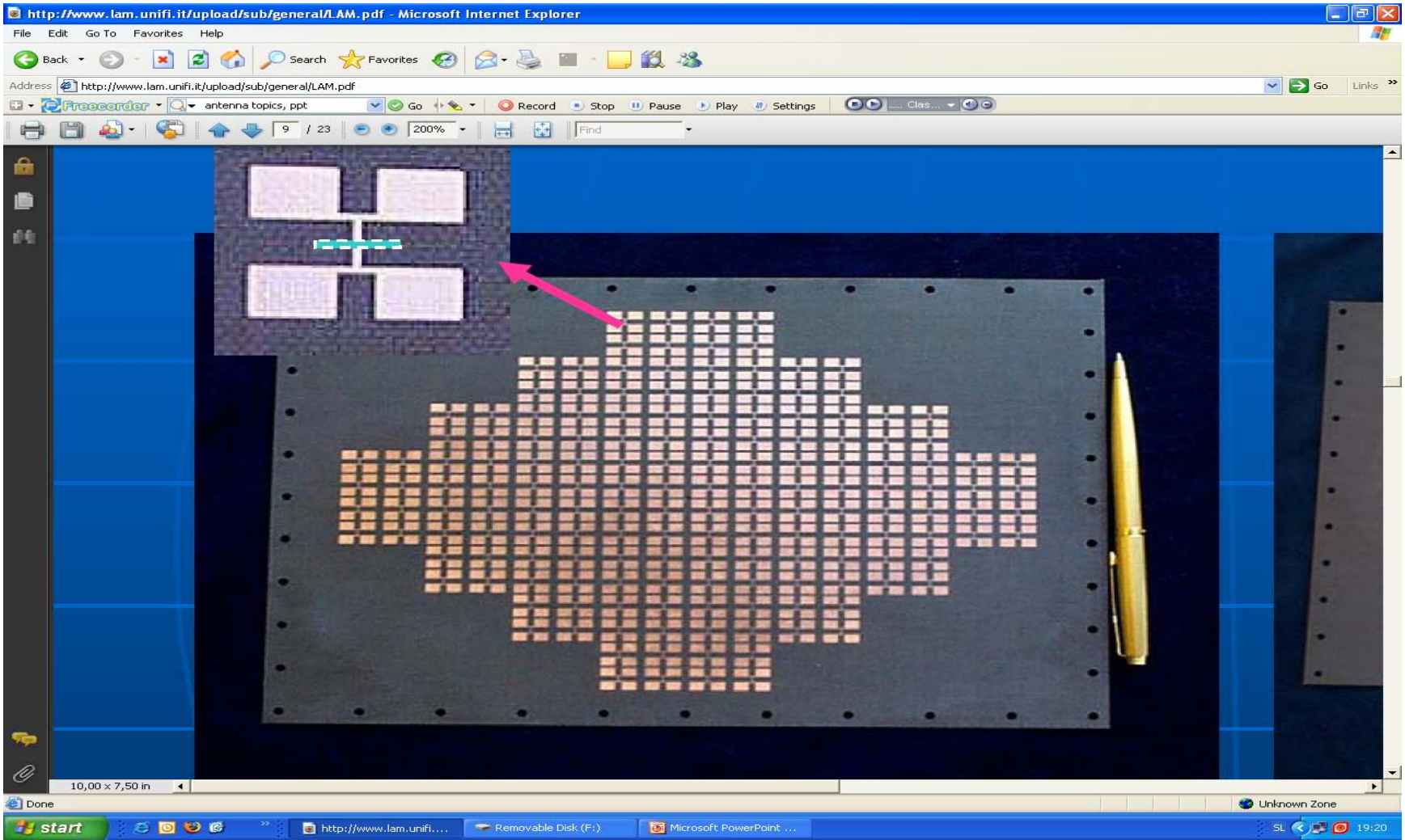
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