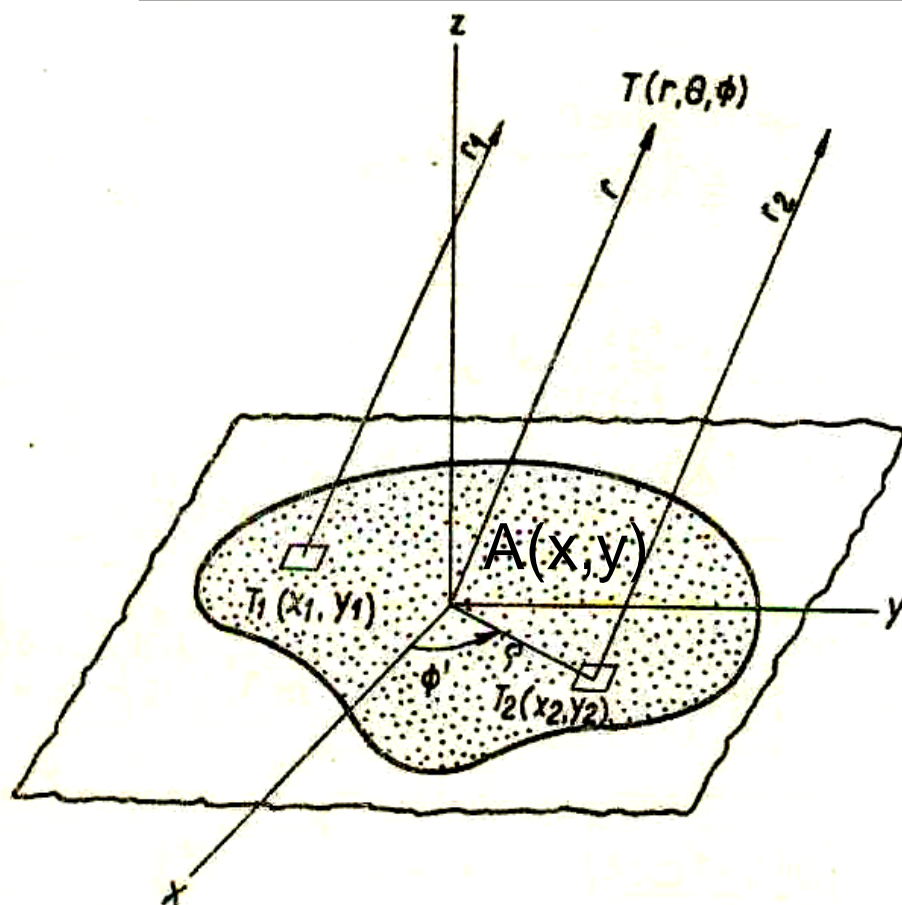


Zvezne skupine in odprtine

$$F(u,v) = F^{-1}(A(x,y))$$

$$A(x,y) = F(F(u,v))$$



Mobitel d.d.,
izobraževanje

29. 5. 2009,
predavanje 16

Prof. dr. Jožko Budin

Vsebina

1. Zvezne linearne skupine izotropnih virov.
 - Smerni diagram in porazdelitev vzbujanja sta Fourierjev par.
 - Smerni diagram konstantne in upadajoče distribucije, linearna in kvadratna faza.

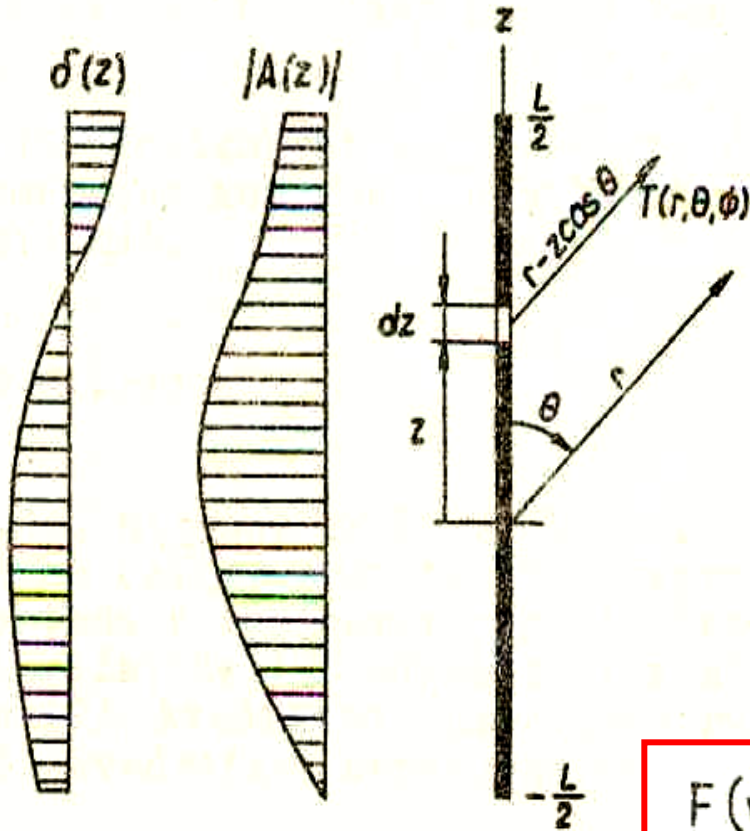
2. Zvezne površinske skupine izotropnih virov
 - Kvadratna in krožna odprtina.
 - Smerni diagram konstantne in upadajoče distribucije, linearna in kvadratna faza.

Smerni diagram skupine izotropnih virov

$$E = K \frac{e^{-j\beta r}}{r} \int_{-\frac{L}{2}}^{\frac{L}{2}} |A(z)| e^{j\delta(z)} e^{j\beta z \cos\theta} dz.$$

Superpozicija prispevkov izotropnih virov na dolžini L

Smerni diagram enodimenzionalne skupine:



$$F(\theta) = \int_{-\frac{L}{2}}^{\frac{L}{2}} A(z) e^{j\beta z \cos\theta} dz.$$

$$A(z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(u) e^{-juz} du.$$

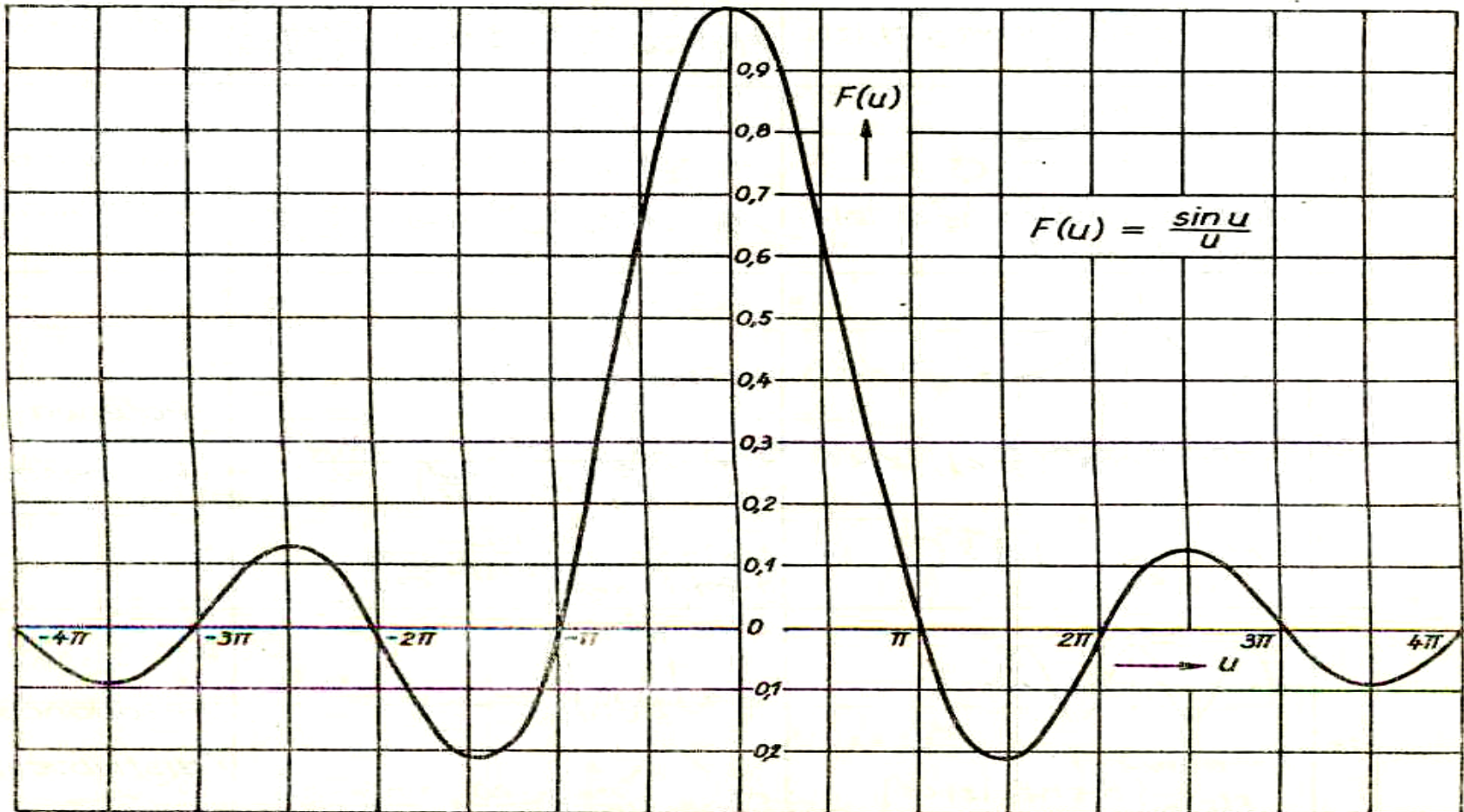
$$F(u) = \int_{-\infty}^{\infty} A(z) e^{juz} dz,$$

Porazdelitev vzbujanja $A(z)$ in smerni diagram $F(u)$ sta Fourierjeva para

$$F(u) = \mathcal{F}^{-1}[A(z)], \quad A(z) = \mathcal{F}[F(u)]$$

Smerni diagram konstantne distribucije 1/2



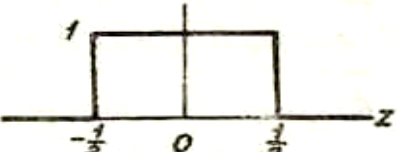

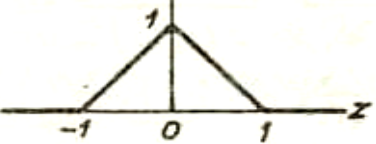
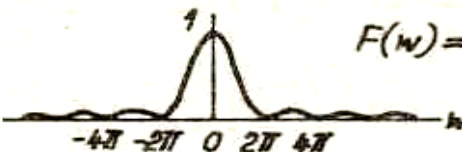
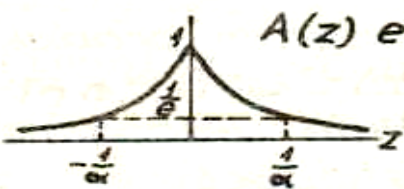
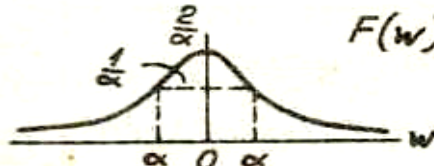
$$F(\theta) = \frac{\sin u}{u} = \frac{\sin \left[\frac{L}{2} (\beta \cos \theta + b) \right]}{\frac{L}{2} (\beta \cos \theta + b)}$$



Fourierjev transform

$$F(w) = \int_{-\infty}^{\infty} A(z) e^{jwz} dz$$

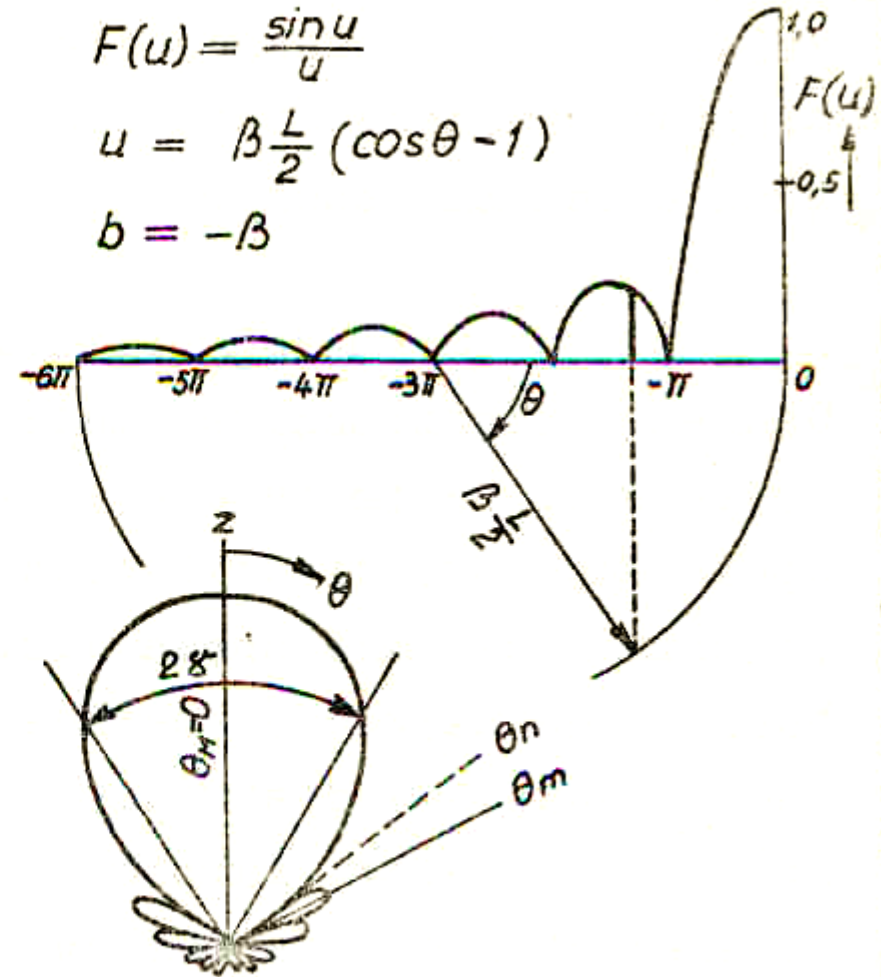
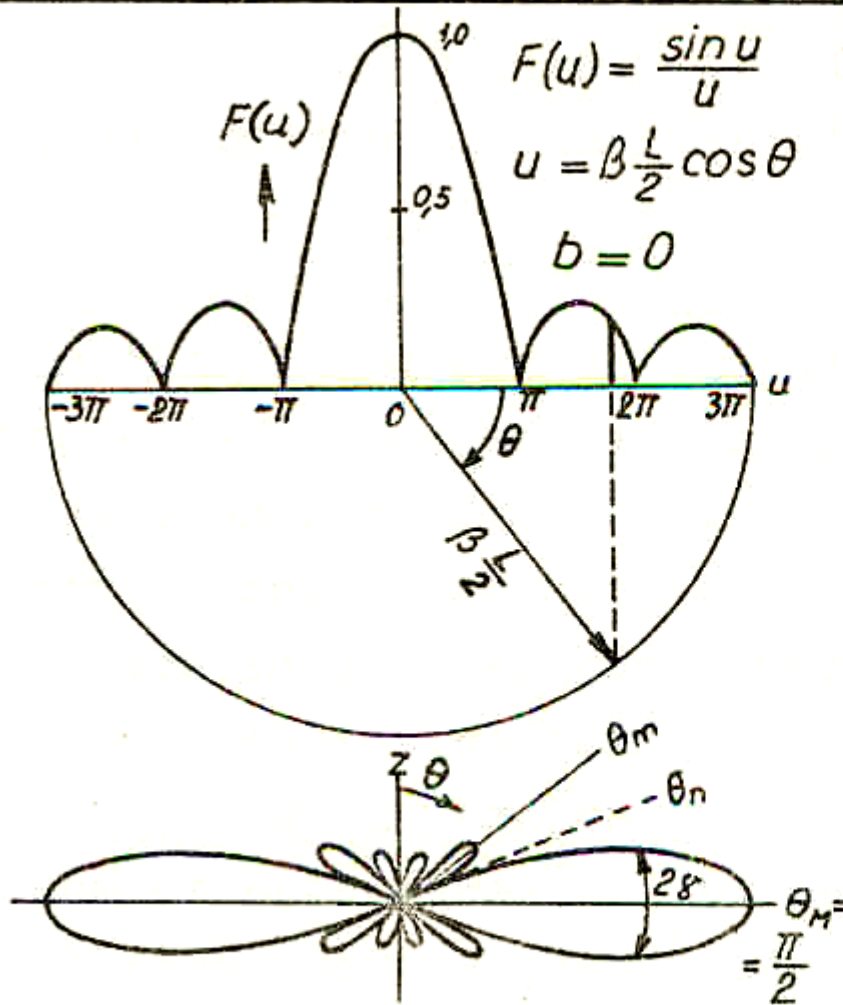
$$A(z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(u) e^{-jwz} dw$$

4	 $A(z) = e^{-\frac{1}{2}z^2}$	 $F(w) = \sqrt{2\pi} e^{-\frac{1}{2}w^2}$	Gaussova distribucija
5	 $A(z) = \begin{cases} 1, & z < \frac{1}{2} \\ 0, & z > \frac{1}{2} \end{cases}$	 $F(w) = \frac{\sin \frac{w}{2}}{\frac{w}{2}}$	Konstantna distribucija
6	 $A(z) = \begin{cases} 1 - z , & z < 1 \\ 0, & z > 1 \end{cases}$	 $F(w) = \frac{\sin^2 \frac{w}{2}}{(\frac{w}{2})^2}$	Trikotna distribucija
7	 $A(z) e^{-\alpha z }$	 $F(w) = \frac{2\alpha}{\alpha^2 + w^2}$	Eksponenčna distribucija

Smerni diagram konstantne distribucije 1/2

BOČNA

OSNA



Lega glavnega snopa

$$\theta_M = \frac{\pi}{2}$$

$$\theta_M = 0$$

Smerni diagram konstantne distribucije 2/2

Bočna skupina $\delta = 0^\circ$

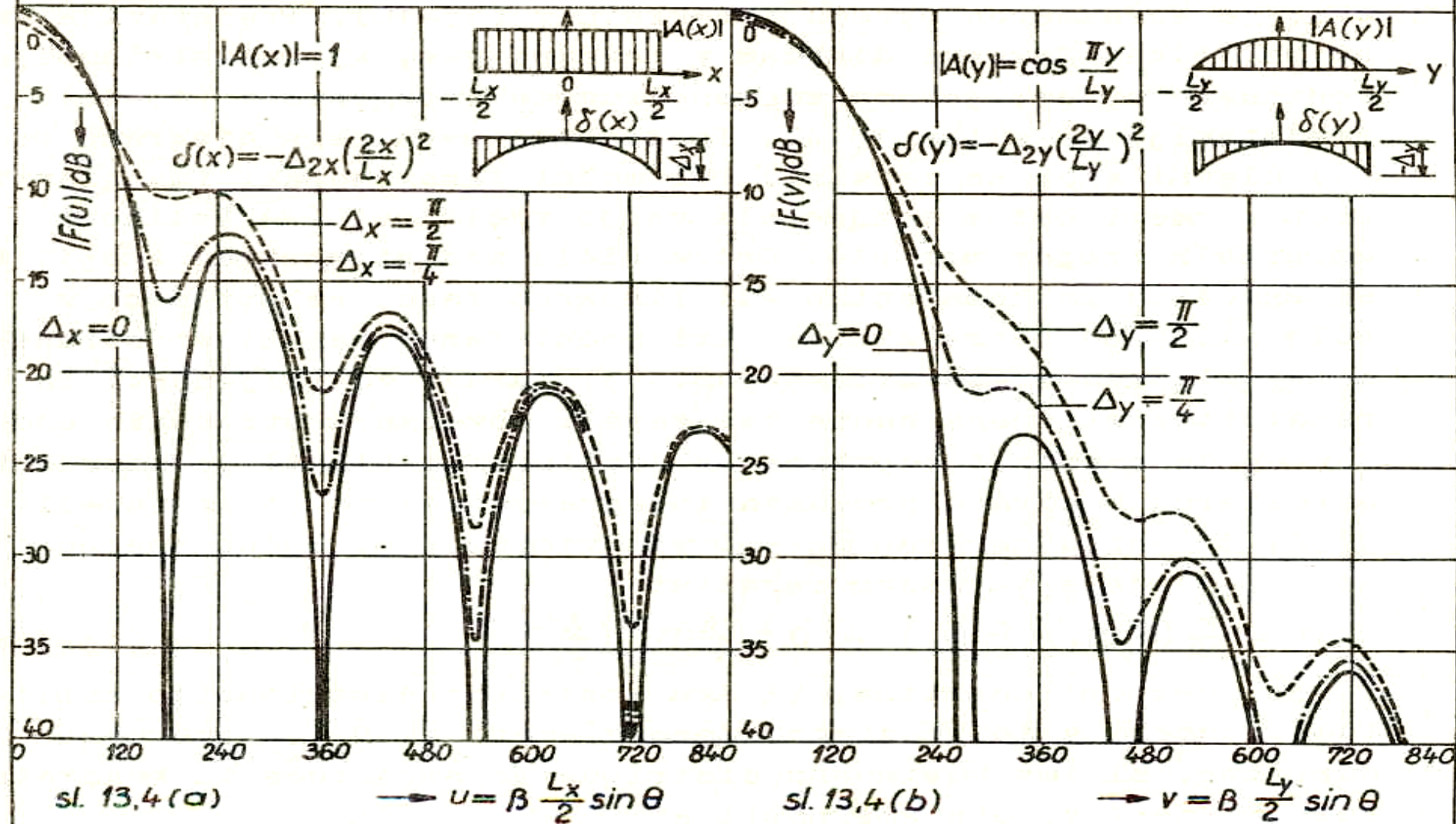
Oсна skupina $\delta = -\beta d^0$

Širina glavnega snopa	
$2\gamma \doteq 0,886 \frac{\lambda}{L}$	$L \gg \lambda$
$2\gamma \doteq 2\sqrt{0,886} \frac{\lambda}{L}$	$L \gg \lambda$
Lega ničel	
$\theta_n = \arccos \frac{n\lambda}{L}, \quad n = \pm 1, \pm 2 \dots$	$\theta_n = \arccos(1 + \frac{n\lambda}{L}), \quad n = -1, -2 \dots$
$\frac{\pi}{2} - \theta_n = \arcsin \frac{n\lambda}{L} \doteq \frac{n\lambda}{L}$	$\theta_n = 2\arcsin(\pm\sqrt{\frac{ n \lambda}{2L}}) \doteq \pm 2\sqrt{\frac{ n \lambda}{2L}}$
Kot med prvima ničloma	
$2\gamma_n \doteq \frac{2\lambda}{L}$	$L \gg \lambda$
$2\gamma_n \doteq 2\sqrt{\frac{2\lambda}{L}}$	$L \gg \lambda$
Lega stranskih snopov	
$\frac{\pi}{2} - \theta_m \doteq \pm(m + \frac{1}{2}) \frac{\lambda}{L} \quad m = 1, 2 \dots$	$\theta_m \doteq \pm 2\sqrt{(m + \frac{1}{2}) \frac{\lambda}{2L}} \quad m = 1, 2 \dots$
Velikost stranskih snopov	
$F(\theta_m) = \frac{(-1)^m}{\sqrt{1+u_m^2}} \doteq \frac{(-1)^m}{\sqrt{1+(m + \frac{1}{2})^2 \pi^2}}$	
Smernost	
$D \doteq \frac{2L}{\lambda}$	$L \gg \lambda$
$D \doteq \frac{4L}{\lambda}$	$L \gg \lambda$

Smerni diagram linearnega vira 1/2

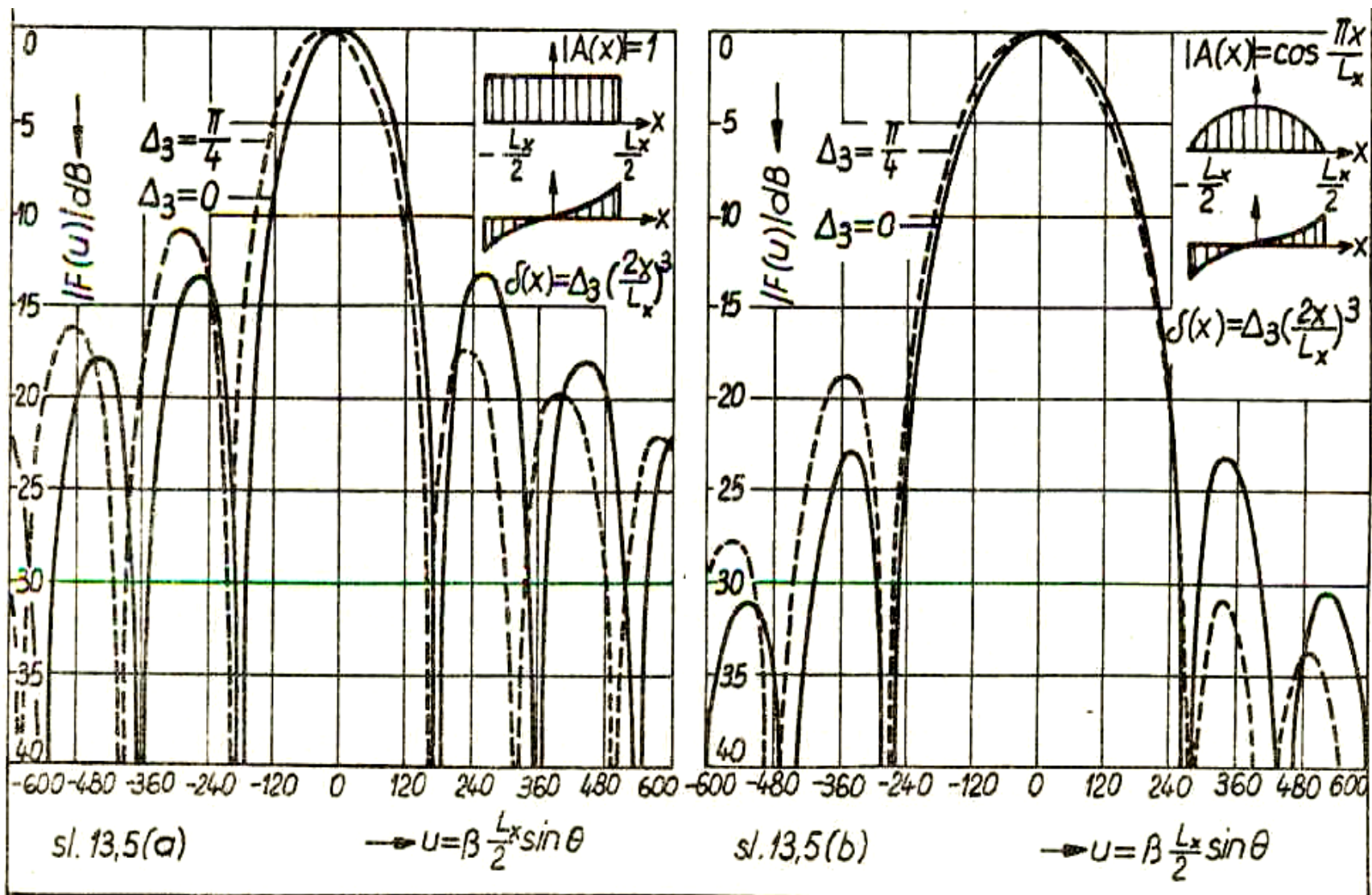
Konstantna in kosinusna amplituda, kvadratna faza

SEVALNI DIAGRAMI PRI KVADRATNI IN KUBNI FAZI

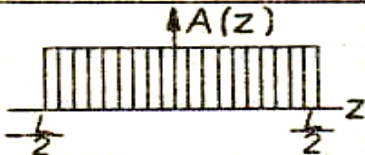
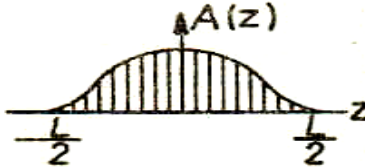
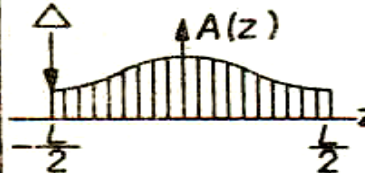


Smerni diagram linearnega vira 2/2

Konstantna in kosinusna amplituda, kubna faza



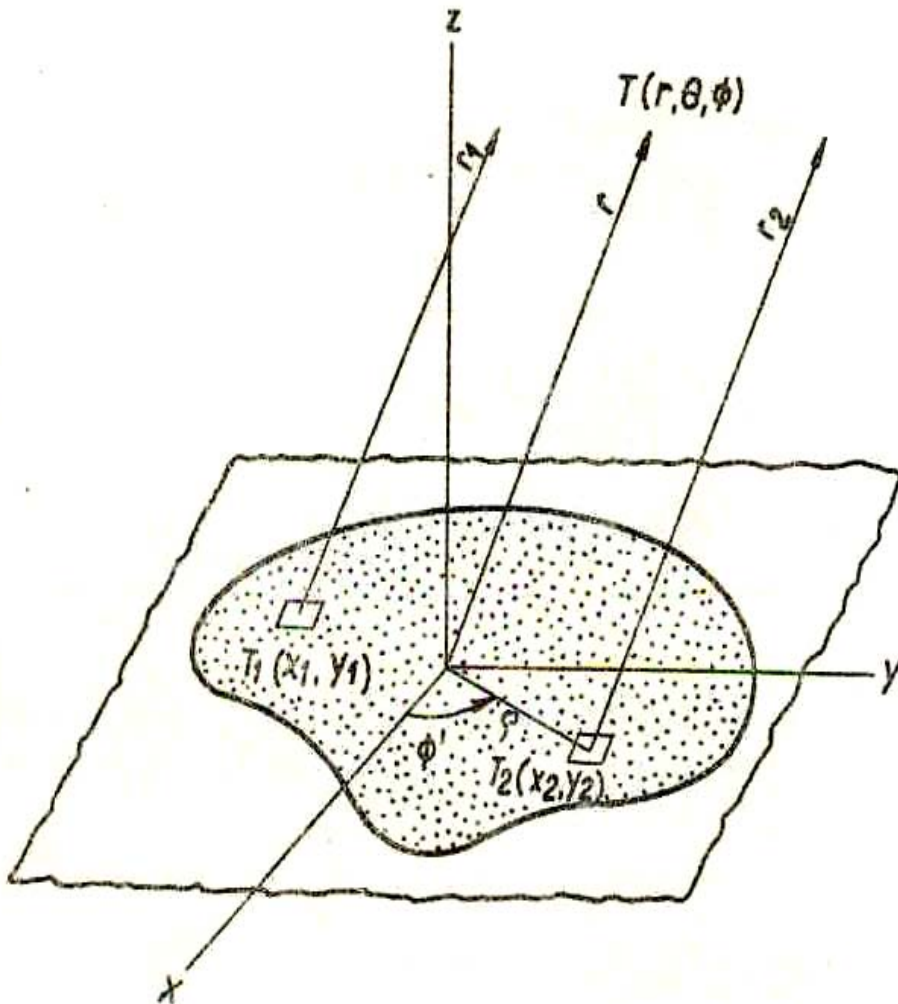
Podatki za upadajoče enodimenzionalne distribucije, 1/2

Diagram	Distribucija $A(z)$	Δ	Širina glavnega snopa 2σ v radianih ali stopinjah	Kot med prvima ničloma $2\gamma_n$ v radianih ali stopinjah
	Konstanta $A(z) = 1$	1	$0,886 \frac{\lambda}{L}$ $50,8 \frac{\lambda}{L}$	$2 \frac{\lambda}{L}$ $115 \frac{\lambda}{L}$
	Potenca kosinusa $A(z) = \cos \frac{\pi}{L} z$	0	$1,2 \frac{\lambda}{L}$ $68,8 \frac{\lambda}{L}$	$3 \frac{\lambda}{L}$ $171,8 \frac{\lambda}{L}$
	$A(z) = \cos^2 \frac{\pi}{L} z$	0	$1,45 \frac{\lambda}{L}$ $83,2 \frac{\lambda}{L}$	$4 \frac{\lambda}{L}$ $229,2 \frac{\lambda}{L}$
	$A(z) = \cos^3 \frac{\pi}{L} z$	0	$1,66 \frac{\lambda}{L}$ $95,3 \frac{\lambda}{L}$	$5 \frac{\lambda}{L}$ $287 \frac{\lambda}{L}$
	$A(z) = \Delta + (1-\Delta) \cos \frac{\pi}{L} z$	0,6	$0,94 \lambda/L$	$2,22 \lambda/L$
		0,4	λ/L	$2,39 \lambda/L$
		0,2	$1,08 \lambda/L$	$2,62 \lambda/L$
	Potenca kosinusa $A(z) = \Delta + (1-\Delta) \cos^2 \frac{\pi}{L} z$	0,6	$0,98 \lambda/L$	$2,3 \lambda/L$
		0,4	$1,16 \lambda/L$	$2,51 \lambda/L$
		0,2	$1,18 \lambda/L$	$3,36 \lambda/L$

Podatki za upadajoče enodimenzionalne distribucije, 2/2

Slabljenje prvega stranskega snopa [dB]	Izkoristek η	Sevalni diagram $F(\theta)$
13,2	1	$\frac{\sin(\beta \frac{L}{2} \cos \theta)}{\beta \frac{L}{2} \cos \theta}$
23	0,81	$\frac{\cos(\beta \frac{L}{2} \cos \theta)}{1 - (\frac{2}{\pi} \beta \frac{L}{2} \cos \theta)^2}$
32	0,667	$\frac{\sin(\beta \frac{L}{2} \cos \theta)}{\beta \frac{L}{2} \cos \theta} \frac{1}{1 - (\frac{1}{\pi} \beta \frac{L}{2} \cos \theta)^2}$
40	0,575	$\frac{\cos(\beta \frac{L}{2} \cos \theta)}{[1 - (\frac{2}{\pi} \beta \frac{L}{2} \cos \theta)^2][1 - (\frac{2}{3\pi} \beta \frac{L}{2} \cos \theta)^2]}$
16	0,975	$\Delta \frac{\sin(\beta \frac{L}{2} \cos \theta)}{\beta \frac{L}{2} \cos \theta} + \frac{2}{\pi} (1 - \Delta) \frac{\cos(\beta \frac{L}{2} \cos \theta)}{1 - (\frac{2}{\pi} \beta \frac{L}{2} \cos \theta)^2}$
18,6	0,95	
21,5	0,915	
18,7	0,97	$(1 + \Delta) \frac{\sin(\beta \frac{L}{2} \cos \theta)}{\beta \frac{L}{2} \cos \theta} + \frac{1}{\pi^2} (1 - \Delta) \sin(\beta \frac{L}{2} \cos \theta) \frac{\beta \frac{L}{2} \cos \theta}{1 - (\frac{1}{\pi} \beta \frac{L}{2} \cos \theta)^2}$
24,3	0,94	
30,3	0,885	

Zvezna skupina na ploskvi



Distribucija in smerni diagram pravokotne skupine:

$$A(x,y) = A e^{j b_x x} e^{j b_y y}, \quad -\frac{L_x}{2} \leq x \leq \frac{L_x}{2},$$

$$-\frac{L_y}{2} \leq y \leq \frac{L_y}{2}.$$

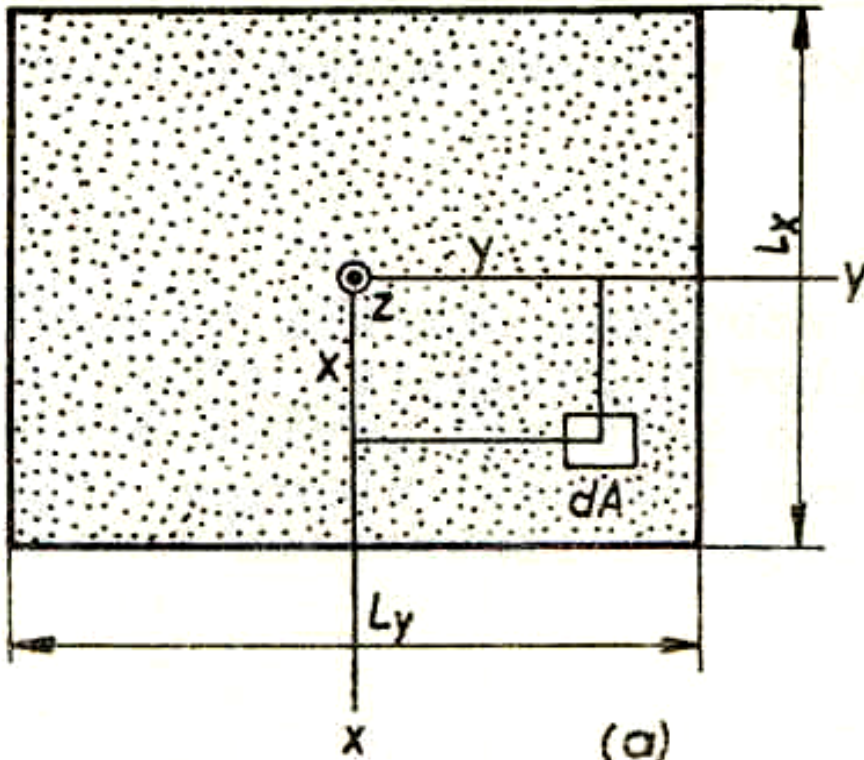
$$F(\theta, \phi) = \frac{\sin u}{u} \frac{\sin v}{v}, \quad u = \frac{L_x}{2} (\beta \sin \theta \cos \phi + b_x)$$

$$v = \frac{L_y}{2} (\beta \sin \theta \sin \phi + b_y)$$

Smerni diagram je odvisen od:

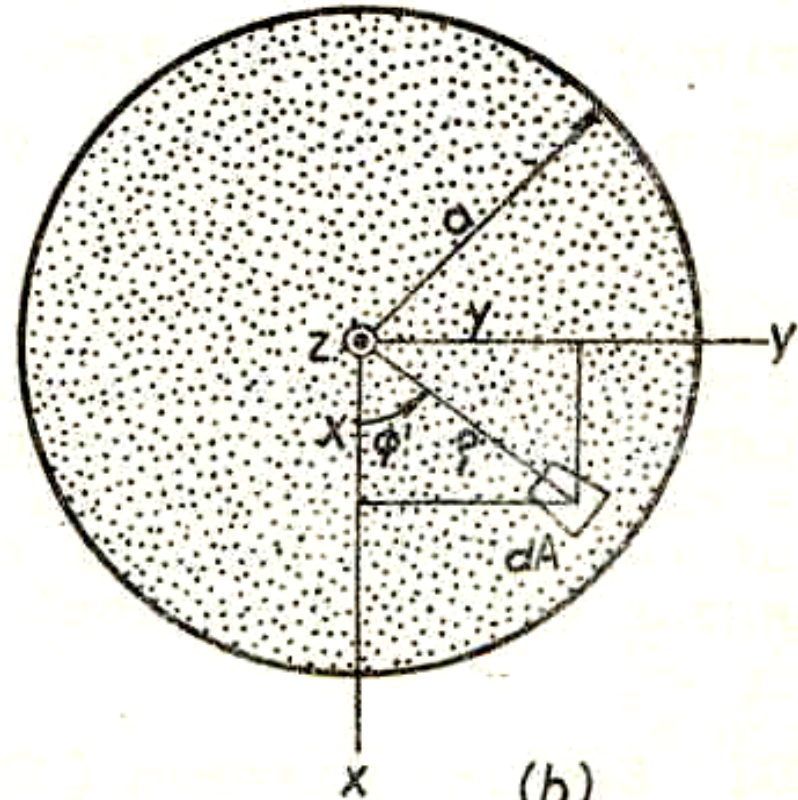
- oblike površine
- distribucije faze
- distribucije amplitude

Pravokotna in krožna skupina



(a)

Ravninska pravokotna skupina

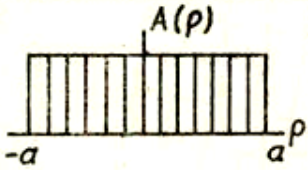
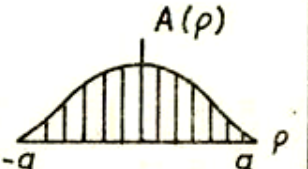
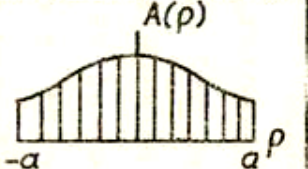


(b)

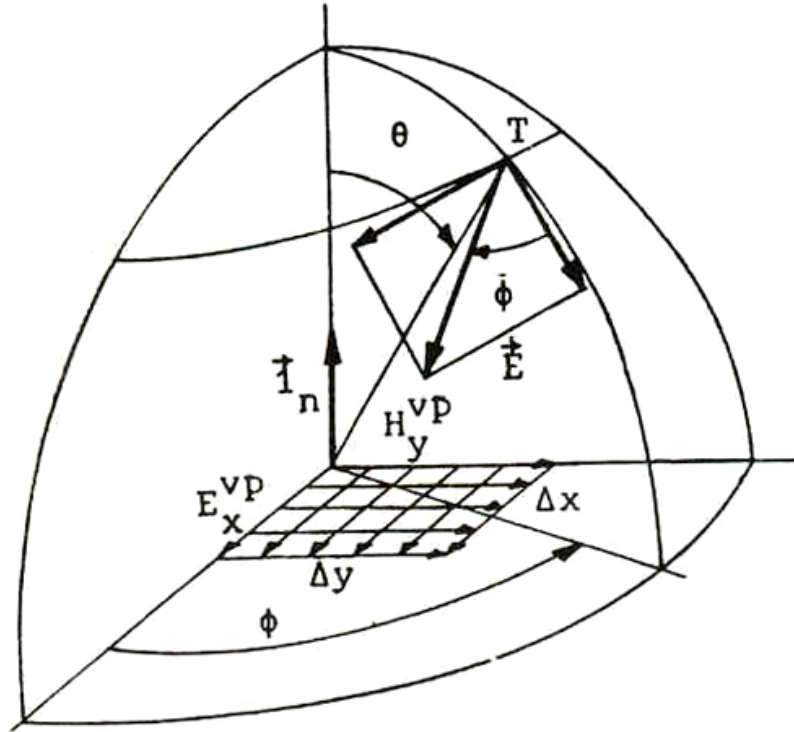
Ravninska krožna skupina

Dana je porazdelitev amplitude, faze in polarizacije polja na ploskvi.

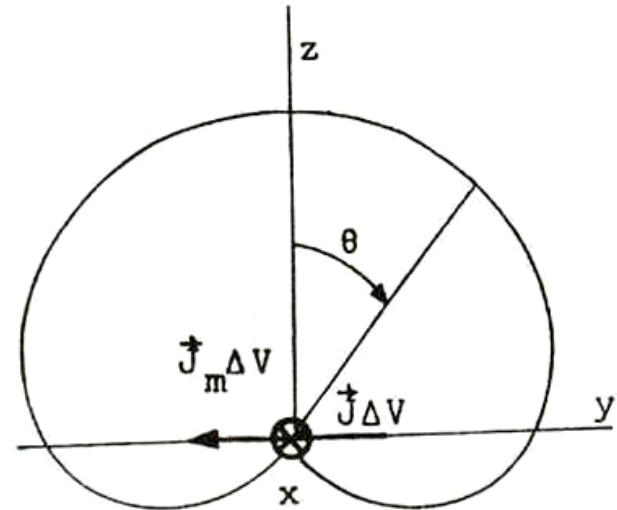
Smerni diagrami tipične krožne skupine z upadajočo distribucijo

Distribucija $A(\rho)$		Δ	Širina glavnega snopa $2\theta_n$ [rad] in [°]	Kot med prvima ničloma $2\theta_n$ [rad] in [°]	Slabljenje prvega stranskega snopa [dB]	η	Sevalni diagram
	$A(\rho) = 1$		$1,02 \frac{\lambda}{2a}$ $58,5 \frac{\lambda}{2a}$	$2,44 \frac{\lambda}{2a}$ $140 \frac{\lambda}{2a}$	17,6	1	$\frac{2J_1(\beta a \sin \theta)}{\beta a \sin \theta}$
	$A(\rho) = 1 - \left(\frac{\rho}{a}\right)^2$		$1,27 \frac{\lambda}{2a}$ $72,7 \frac{\lambda}{2a}$	$3,26 \frac{\lambda}{2a}$ $187 \frac{\lambda}{2a}$	24,6	0,75	$\frac{8J_2(\beta a \sin \theta)}{(\beta a \sin \theta)^2}$
	$A(\rho) = \left(1 - \left(\frac{\rho}{a}\right)^2\right)^2$		$1,47 \frac{\lambda}{2a}$ $84,3 \frac{\lambda}{2a}$	$4,06 \frac{\lambda}{2a}$ $232,5 \frac{\lambda}{2a}$	30,6	0,56	$\frac{48J_3(\beta a \sin \theta)}{(\beta a \sin \theta)^3}$
	$A(\rho) = \left(1 - \left(\frac{\rho}{a}\right)^2\right)^3$		$1,65 \frac{\lambda}{2a}$ $94,6 \frac{\lambda}{2a}$	$4,84 \frac{\lambda}{2a}$ $277 \frac{\lambda}{2a}$		0,44	$\frac{384(\beta a \sin \theta)}{(\beta a \sin \theta)^4}$
	$A(\rho) = \Delta + (1-\Delta)\left(1 - \left(\frac{\rho}{a}\right)^2\right)$	0,32	$1,17 \frac{\lambda}{2a}$		21	0,81	$\Delta \frac{2J_1(\beta a \sin \theta)}{\beta a \sin \theta} + (1-\Delta) \frac{4J_2(\beta a \sin \theta)}{(\beta a \sin \theta)^2}$
		0,25	$1,2 \frac{\lambda}{2a}$		22	0,79	
		0,18	$1,24 \frac{\lambda}{2a}$		23,5	0,77	

Huygensov vir



Vpadno TEM polje na ploskvici in sevano linearno polarizirano polje vira v prostoru.

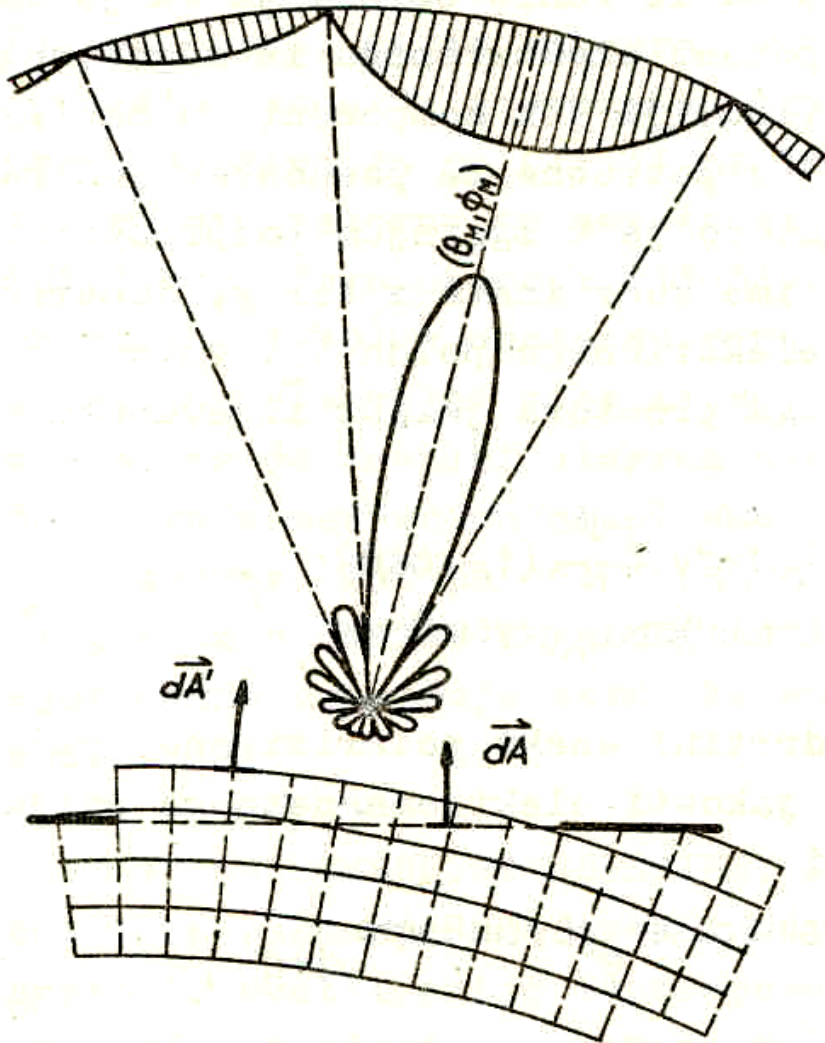


Ekvivalentni sekundarni tokovni vir in rotacijsko simetričen smerni diagram v prostoru. Vir **ne seva v smeri nazaj** proti primarnemu viru, odkoder izhaja. Polje v smeri naprej se dvakrano ojačuje.

$$\vec{E} = \hat{i}_\theta E_\theta + \hat{i}_\phi E_\phi = (\hat{i}_\theta \cos\phi - \hat{i}_\phi \sin\phi) j \frac{E_x^{VP} \Delta A}{2\lambda} (1 + \cos\theta) \frac{e^{-jkr}}{r},$$

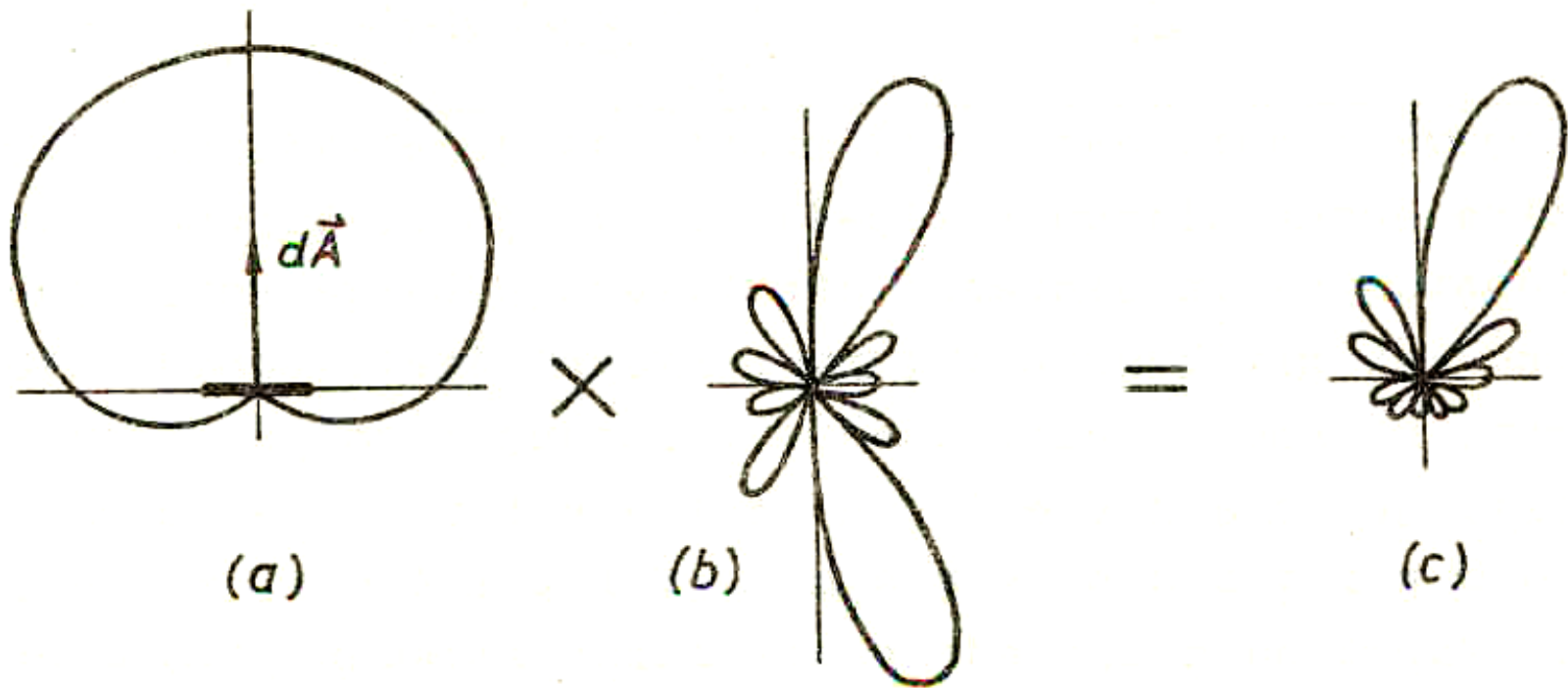
$$\vec{H} = \hat{i}_\theta \left(-\frac{E_\phi}{Z_0}\right) + \hat{i}_\phi \frac{E_\theta}{Z_0} = (\hat{i}_\theta \sin\phi + \hat{i}_\phi \cos\phi) j \frac{E_x^{VP} \Delta A}{2\lambda Z_0} (1 + \cos\theta) \frac{e^{-jkr}}{r}$$

Odprtina kot skupina Huygensovih virov



- Odprtino si predstavljamo kot skupino Huygensovih virov na odprtem delu ravninskega zaslona.
- Amplitudo, fazo in polarizacijo virov določa vpadni val:
- Ravninski vpadni val ima konstantno fazo pri pravokotnem vpadu in linearno fazo pri poševnem vpadu.
- Krogelni val ima kvadratno fazo pri pravokotnem vpadu.

Smerni diagram odprtine

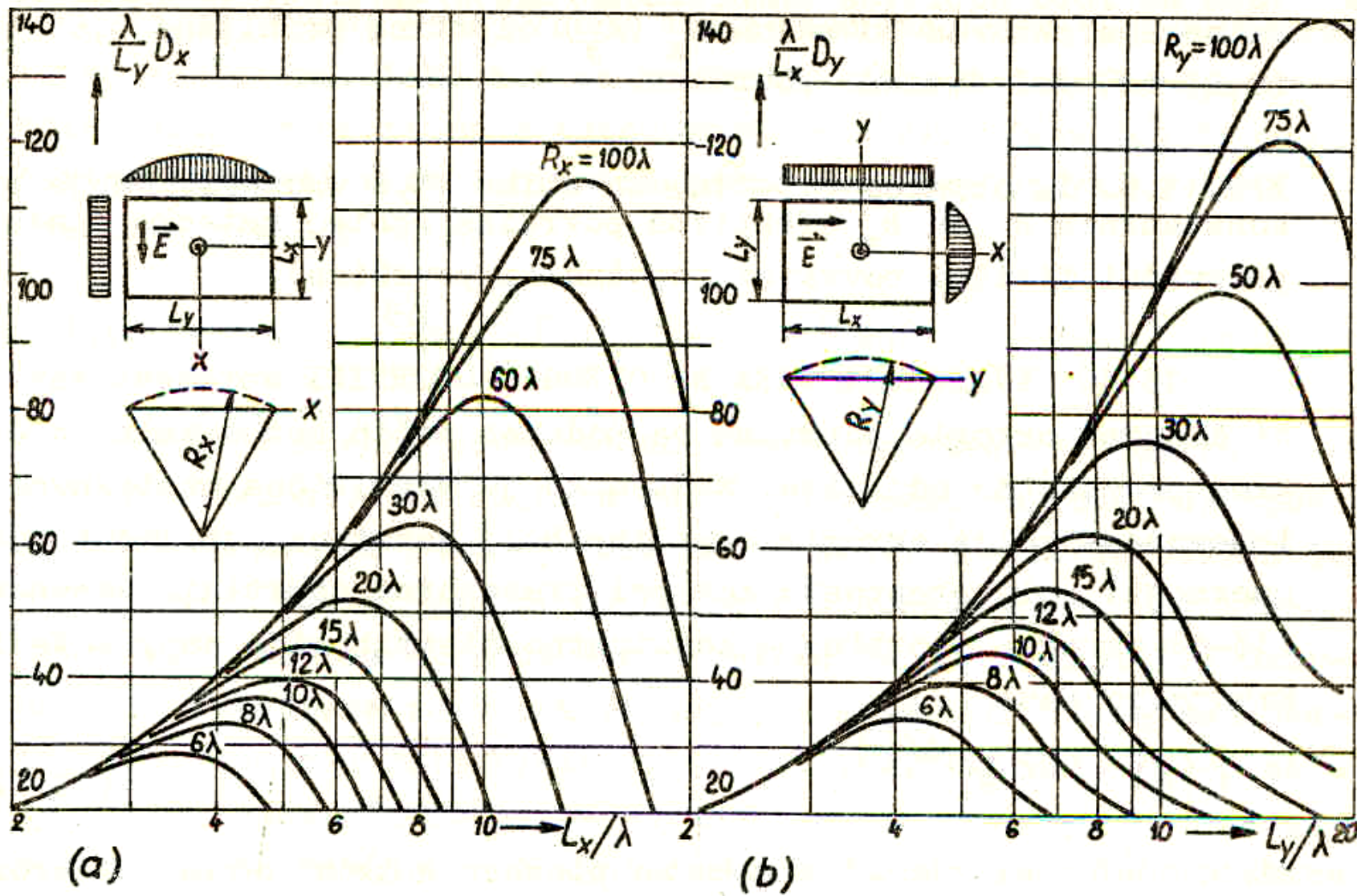


Smerni diagram odprtine (c) je zmnožek kardioidnega diagrama Huygensovega (a) vira in smernega diagrama enako oblikovane in enako vzbujane zvezne skupine izotropnih virov (b)

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

Smernost pravokotne odprtine

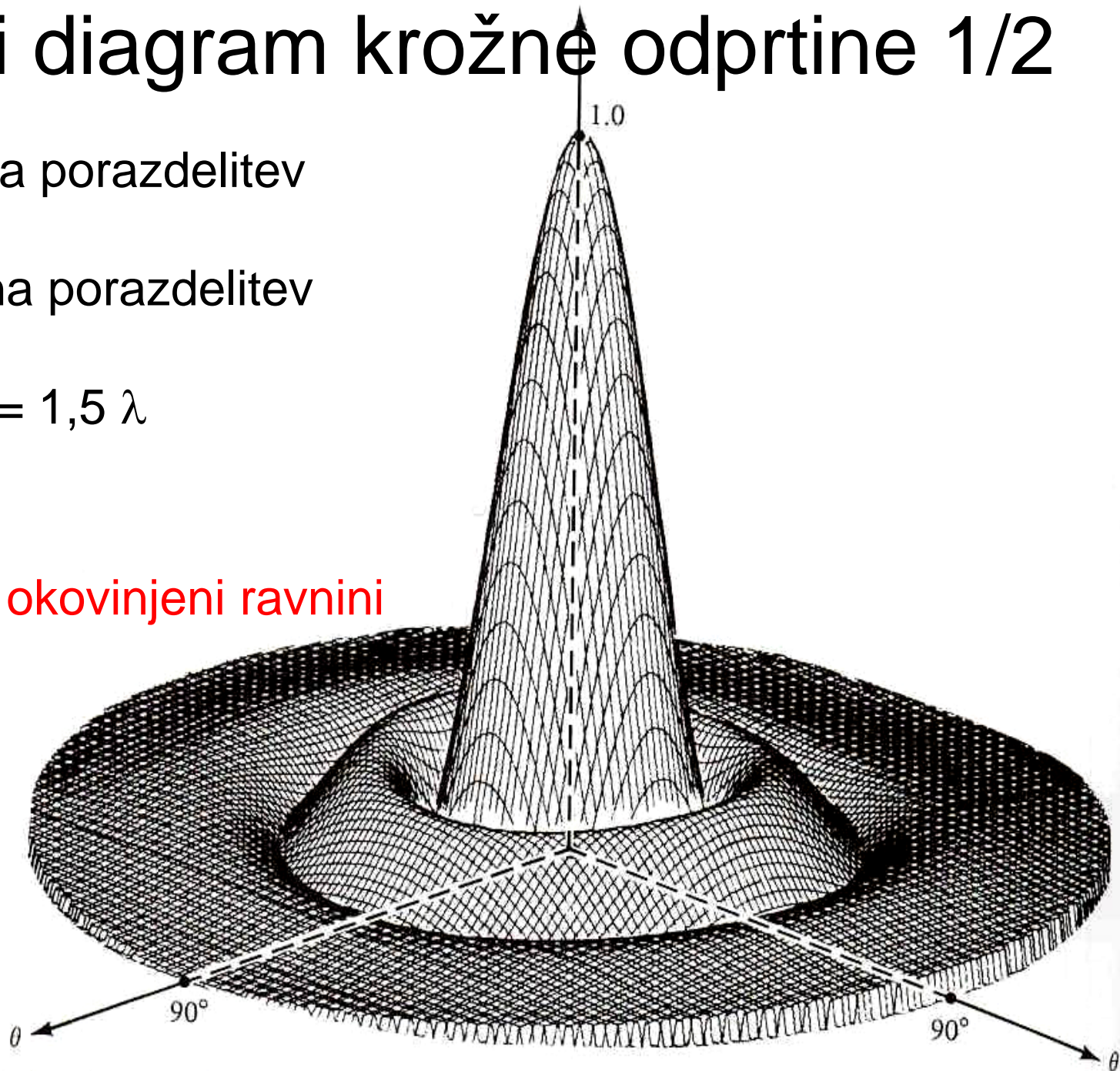
Smernost pravokotne odprtine s kvadratno fazo. Porazdelitev amplitude ustreza vzbujanju z rodnom TE_{01} .



Smerni diagram krožne odprtine 1/2

- Konstantna porazdelitev amplitude
- Konstantna porazdelitev faze
- Polmer $a = 1,5 \lambda$

Odprtina v okovinjeni ravnini

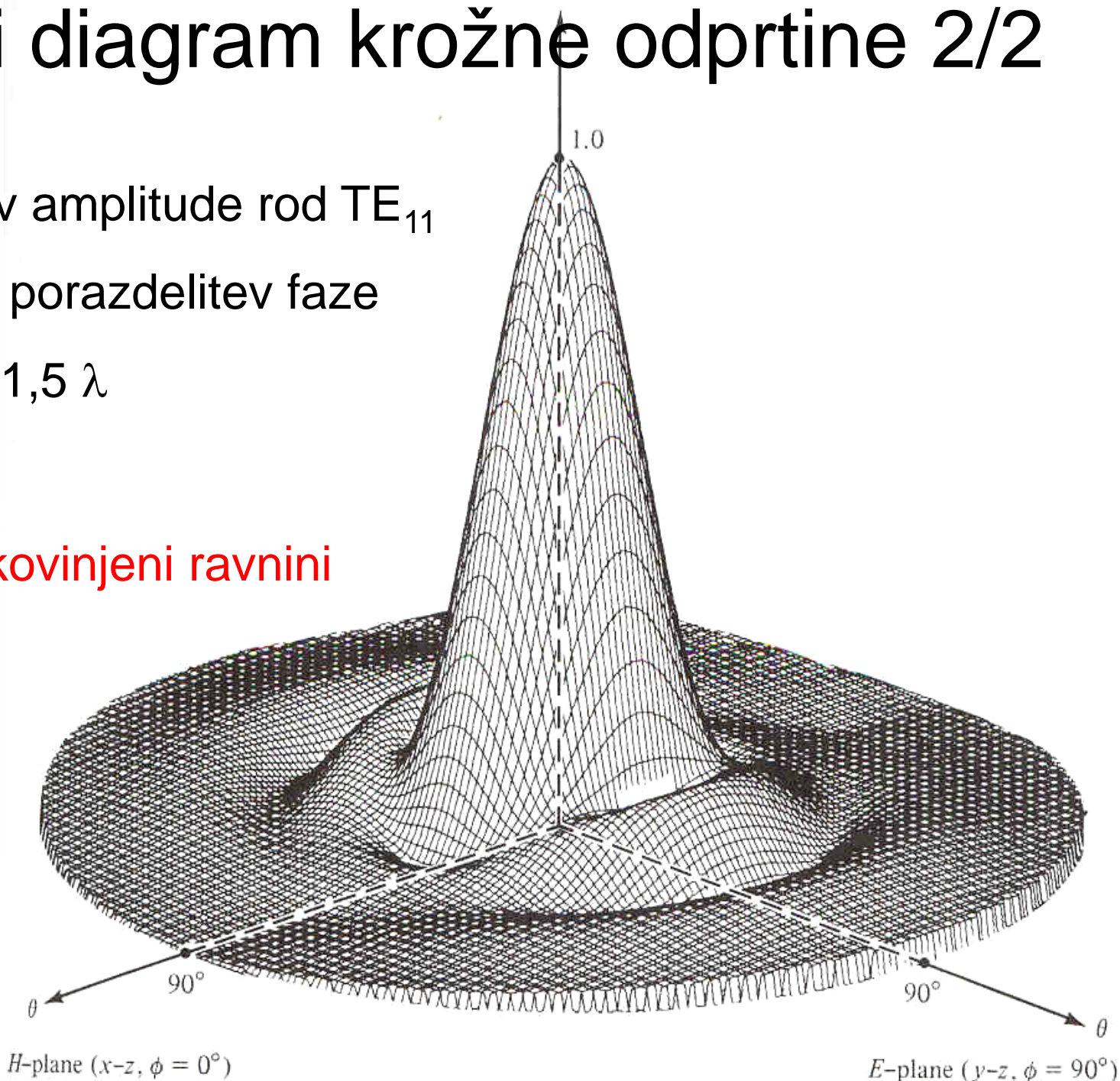


H plane ($\psi = \phi = 0^\circ$)

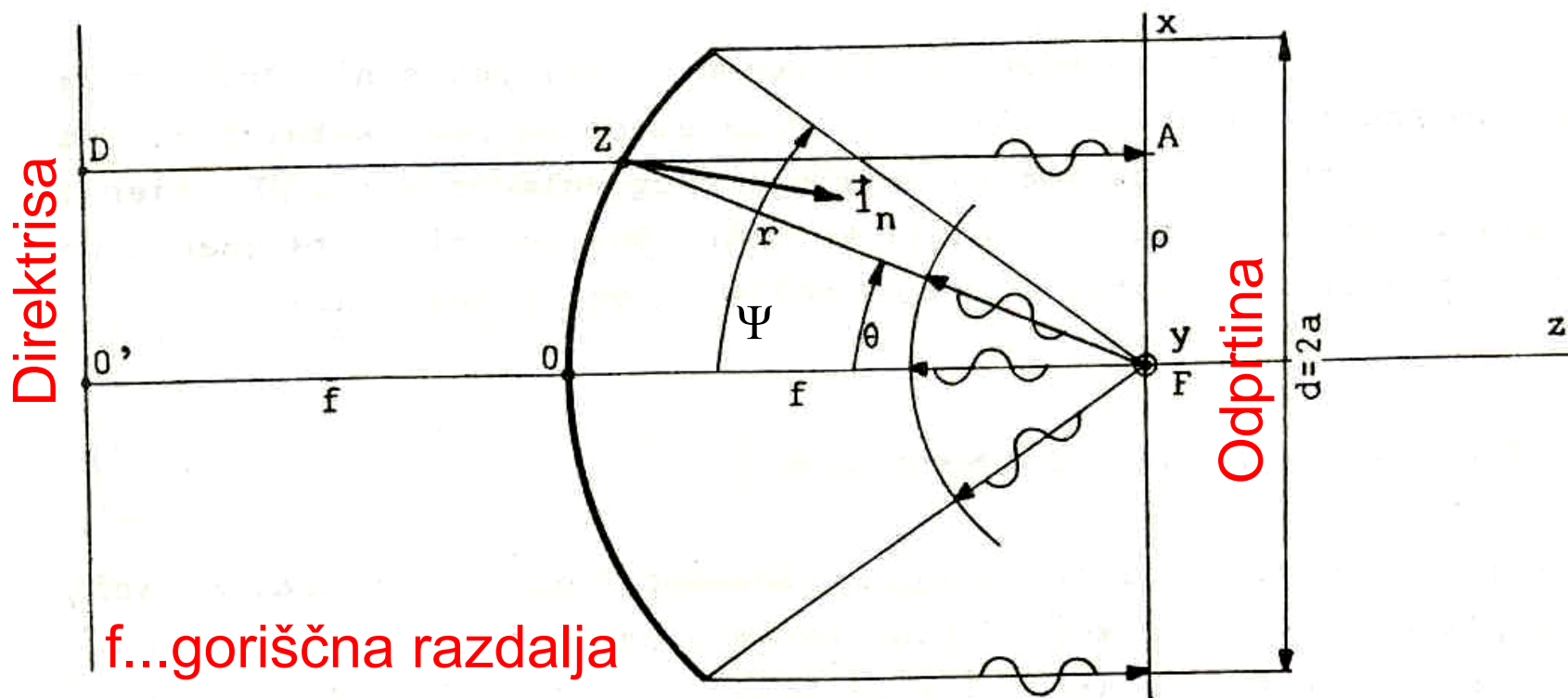
Smerni diagram krožne odprtine 2/2

- Porazdelitev amplitude rod TE_{11}
- Konstantna porazdelitev faze
- Polmer $a = 1,5 \lambda$

Odprtina v okovinjeni ravnini

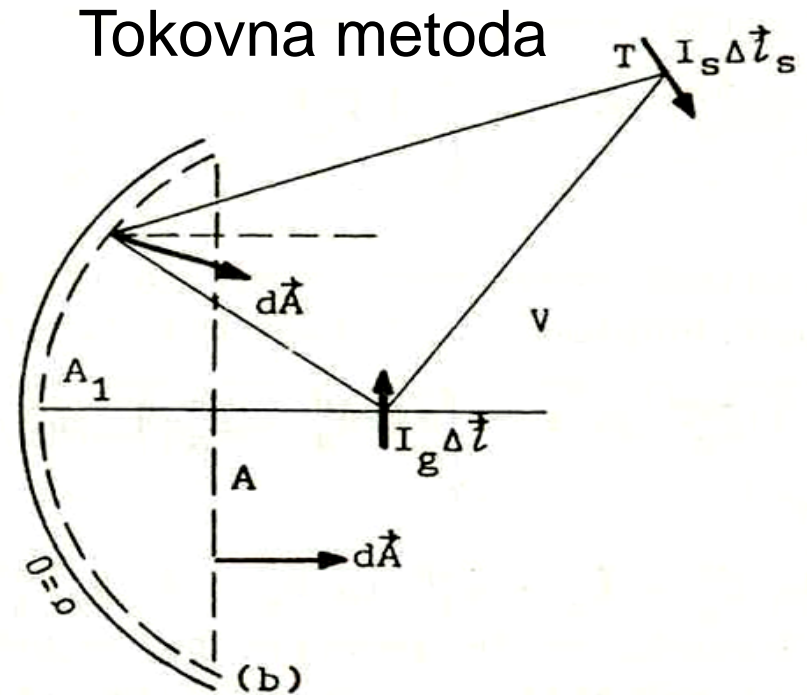
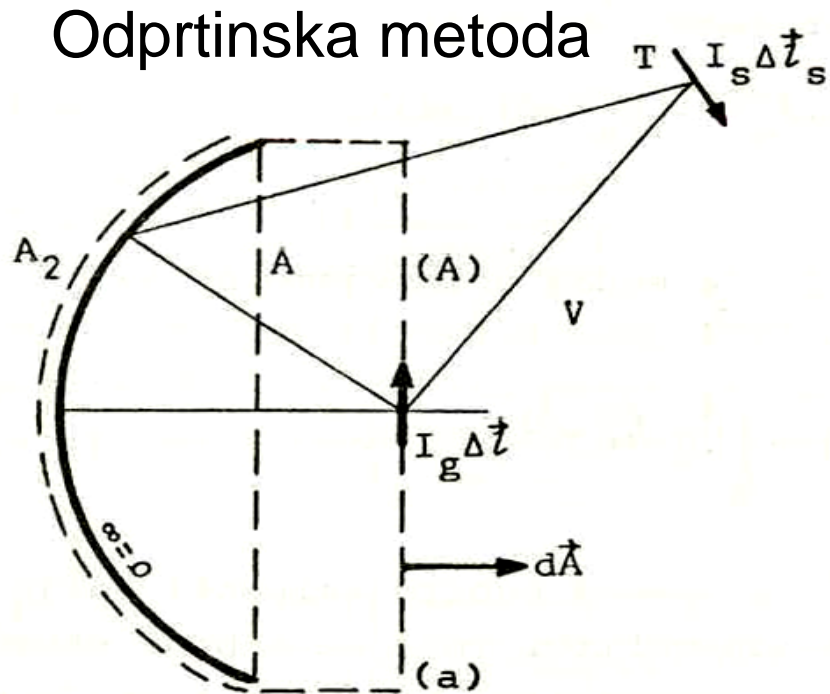


Realizacija skupine s parabolnim zrcalom



- Definijska lastnost paraboloida: $DZ = ZF = r$.
- Dolžina žarka med goriščem in odprtino: $ZF + ZA = DZ + ZA$.
- $DZ + ZA = 2f = \text{konstanta}$.
- Navidezno izhajajo žarki iz ravnine direktrise, zato je polje na odprtini pred zrcalom zaradi enake poti sofazno.

Odprtinska in tokovna metoda



Integracija polja
Huygensovih virov
na ravni odprtini A
ali (A)

Integracija polja
tokovnih elementov
na notranji površini
zrcala

Konec