Corso di “Antenne”

Corso di Laurea in Ingegneria Informatica, Biomedica e delle Telecomunicazioni

Università degli Studi di Napoli “Parthenope”

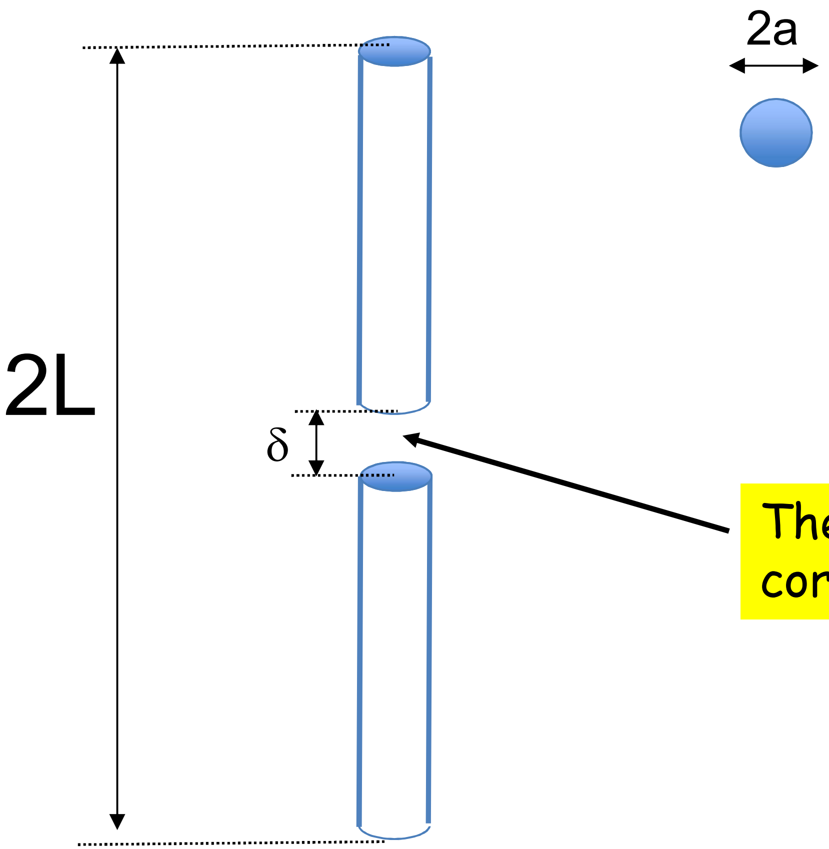
a.a. 2023–2024 – Laurea “Triennale” – Secondo semestre – Terzo anno

Ing. Stefano Perna

Wire antennas

Wire antennas

Wire antennas



$2a \ll \lambda$

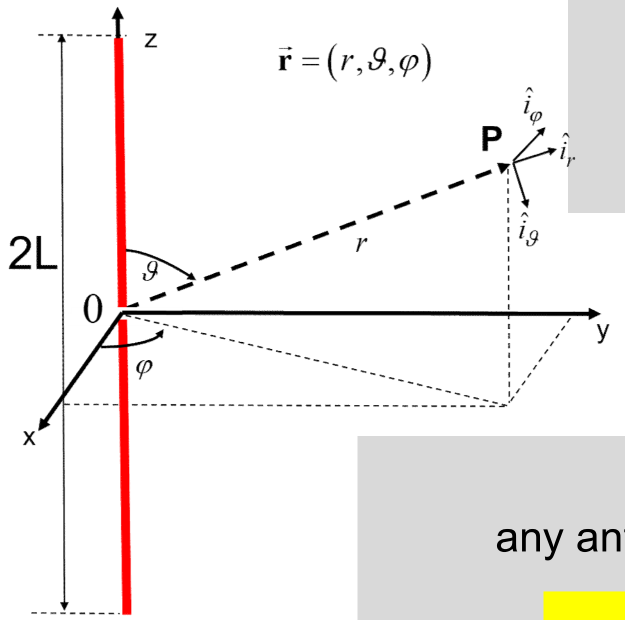
$2a \ll L$

$\delta \ll \lambda$

$\delta \ll L$

The terminals are located in correspondence of this gap

Wire antennas



In the Fraunhofer Region the expression of the radiated field simplifies as

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r} \sin\vartheta \left[\int_{-L}^{L} dz \frac{I(z)}{I_0} \exp(j\beta z \cos\vartheta) \right] \hat{i}_\vartheta$$

Effective length of the wire antenna

.... Memo

any antenna, in the Fraunhofer region, behaves as follows

$$r >> D$$
$$r > \frac{2D^2}{\lambda}$$
$$r >> \lambda$$

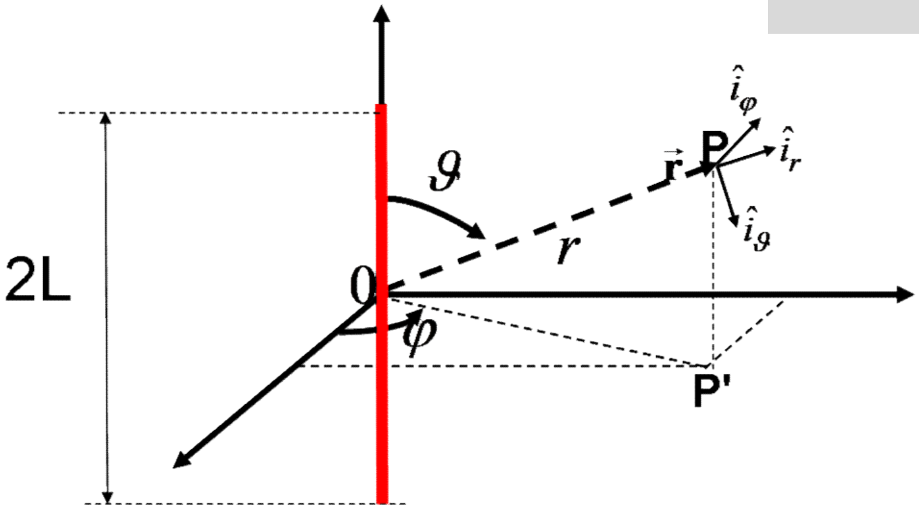
$$\begin{cases} \mathbf{E}(\vec{\mathbf{r}}) = \mathbf{E}(r, \vartheta, \varphi) = \dfrac{j\zeta I}{2\lambda} \dfrac{e^{-j\beta r}}{r} \mathbf{l}(\vartheta, \varphi) \\ \zeta \mathbf{H} = \hat{i}_r \times \mathbf{E} \end{cases}$$

$$\mathbf{l}(\vartheta, \varphi) = l_\vartheta(\vartheta, \varphi)\hat{i}_\vartheta + l_\varphi(\vartheta, \varphi)\hat{i}_\varphi$$ **Effective length**

Current distribution

In wire antennas the source impressed on the antenna is related to the radiated field through the Fourier Transformation rules.

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda}I_0\frac{\exp[-j\beta r]}{r}\left[\sin\vartheta F(\vartheta)\hat{i}_\vartheta\right]$$



$$F(\vartheta) = F(u)\Big|_{u=-\beta\cos\vartheta}$$

$$F(u) = \int_{-L}^{L} dz\, \tilde{I}(z)e^{-juz}$$

$$\tilde{I}(z) = \frac{I(z)}{I_0}$$

Wire antennas: visible region

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r}\left[\sin\vartheta F(\vartheta)\hat{i}_\vartheta\right]$$

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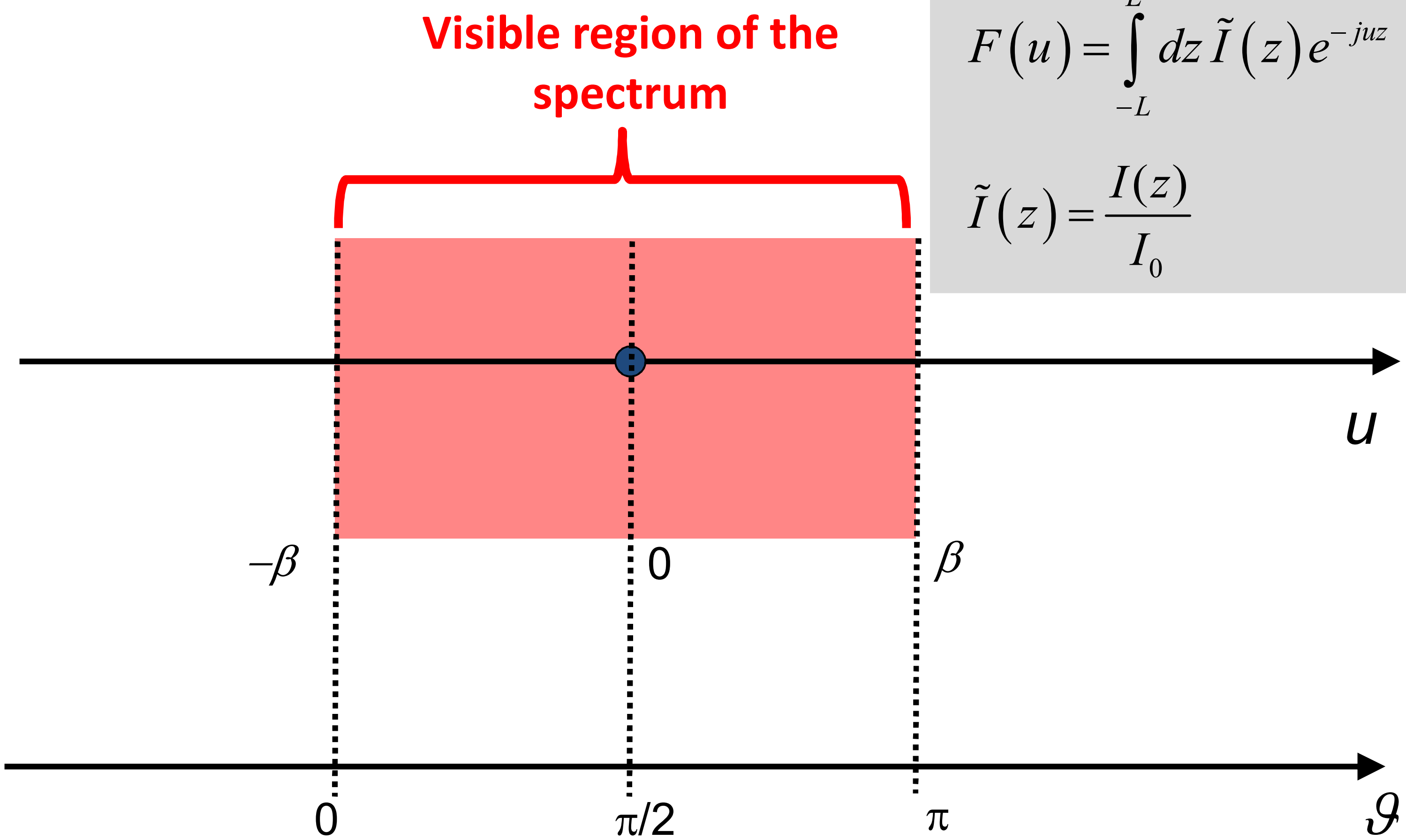

Wire antennas: visible region

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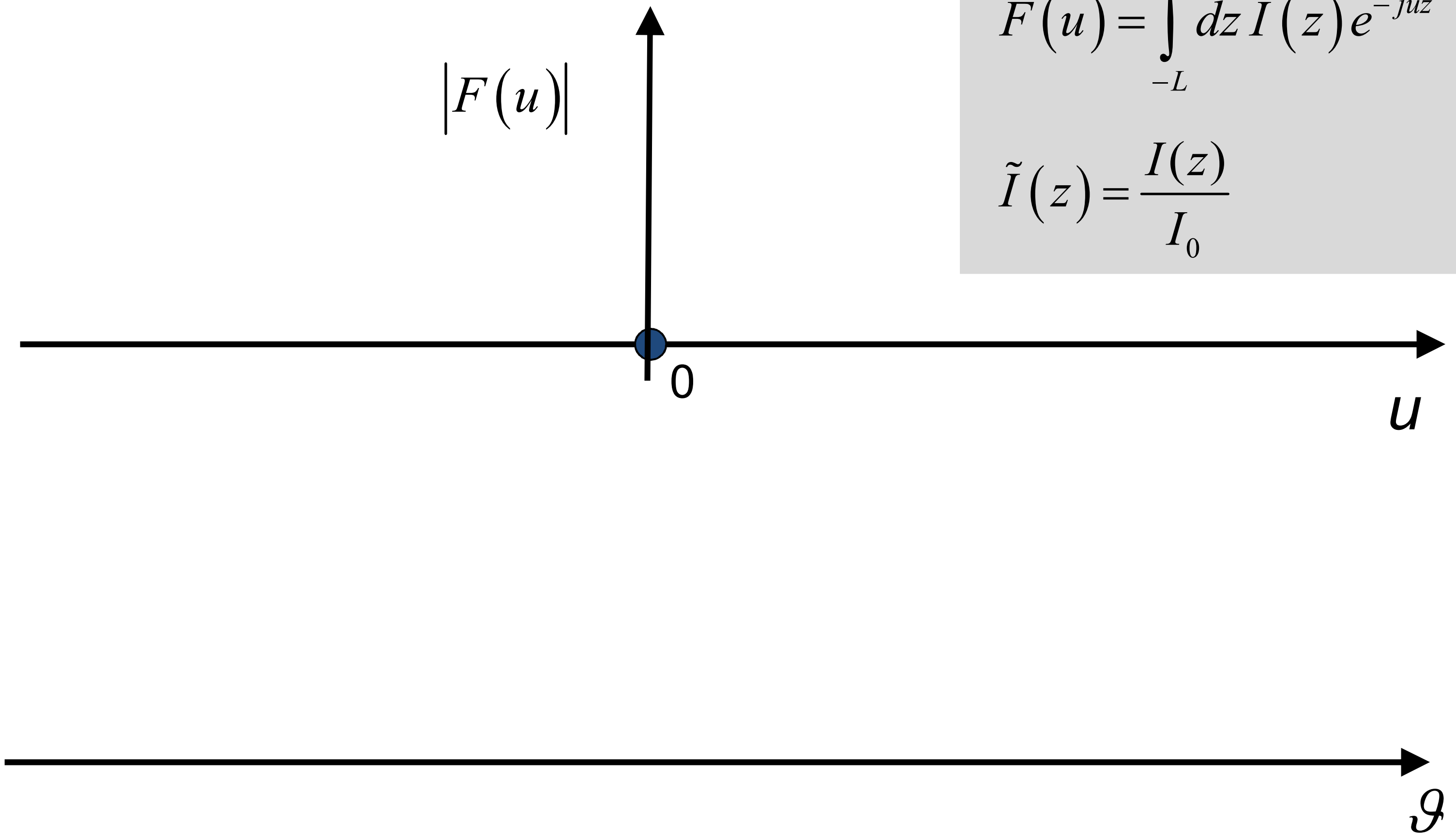

Wire antennas: visible region

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda}I_0\frac{\exp[-j\beta r]}{r}\left[\sin\vartheta F(\vartheta)\hat{i}_\vartheta\right]$$

$$F(\vartheta) = F(u)\Big|_{u=-\beta\cos\vartheta}$$

$$F(u) = \int_{-L}^{L} dz\,\tilde{I}(z)e^{-juz}$$

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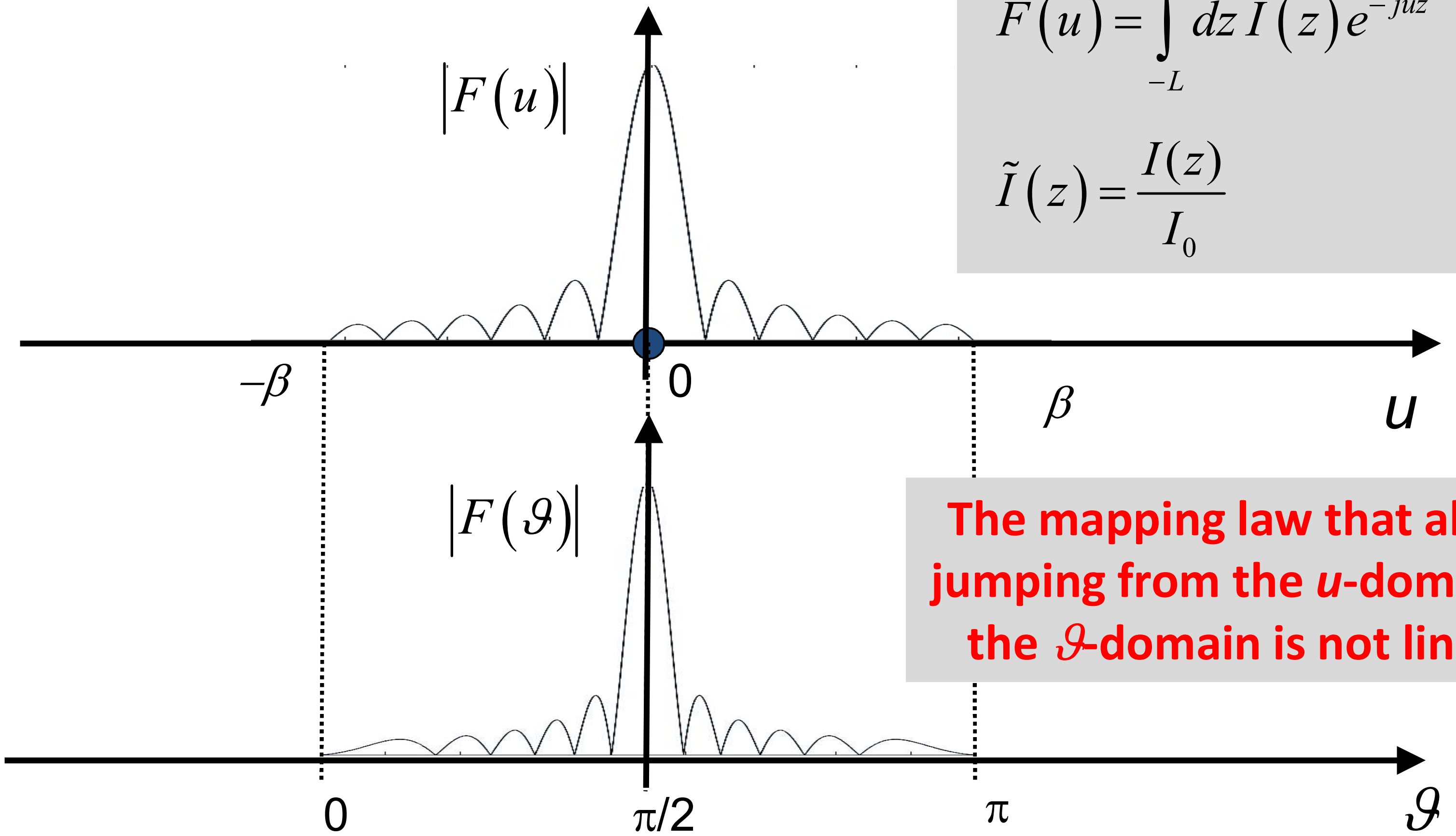


The mapping law that allows jumping from the *u*-domain to the ϑ-domain is not linear!

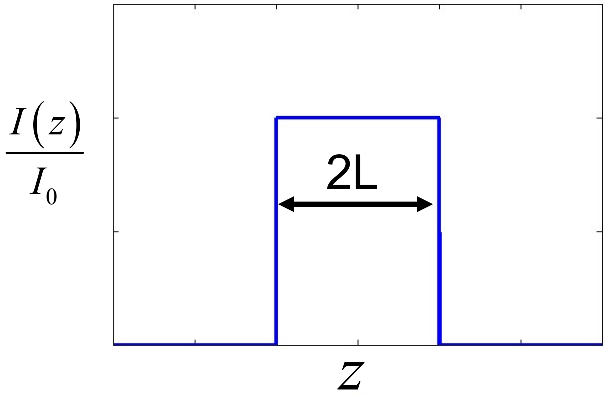
Current distribution

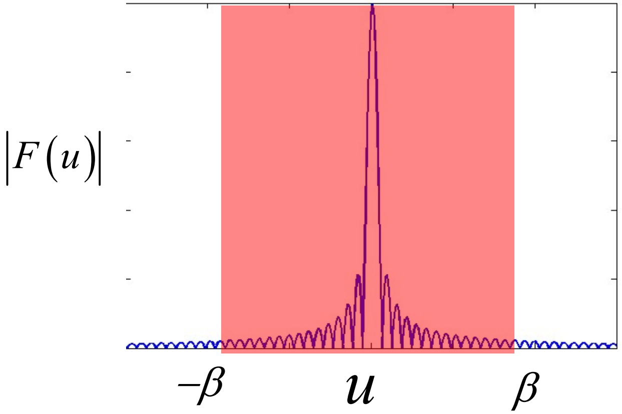
An ideal case

$$\frac{I(z)}{I_0} = \mathrm{rect}\left[\frac{z}{2L}\right]$$

$$F(u) = \int \frac{I(z)}{I_0} e^{-juz}\, dz = 2L\frac{\sin(uL)}{uL}$$

$$u = -\beta \cos\vartheta$$



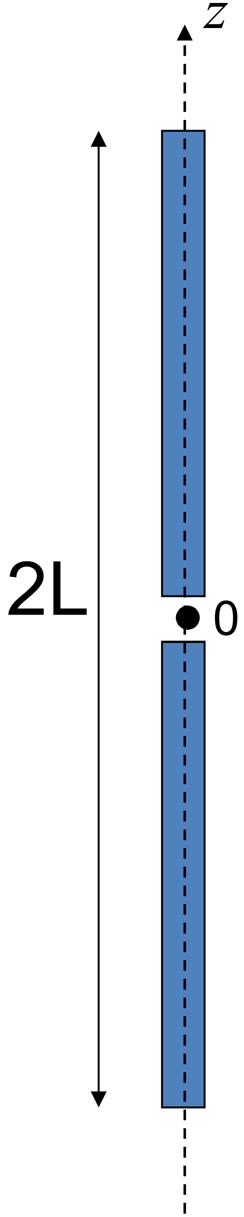


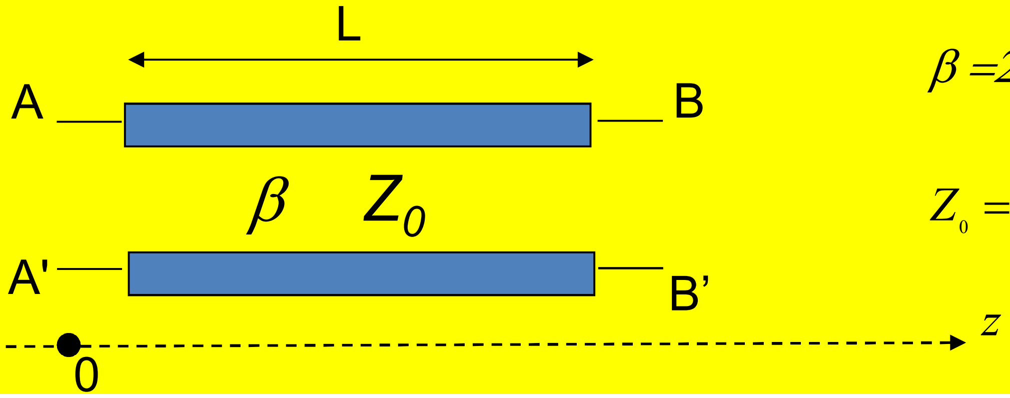
Direction of the Main Lobe $\vartheta_{MB} = \frac{\pi}{2}$

NNBW / HPBW $\mathrm{NNBW} \approx \frac{\lambda}{L} \quad \mathrm{HPBW} \approx 0.88\frac{\lambda}{2L}$

SLL $\mathrm{SLL} = -13.46\, dB$

Hallen Formulation



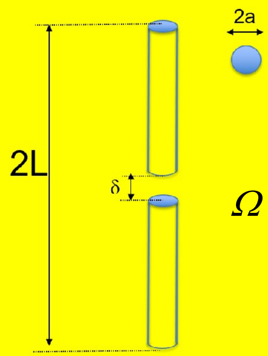


$$\beta = 2\pi/\lambda$$

$$Z_0 = \frac{\zeta \Omega}{2\pi}$$

$$Z_{in} = -jZ_o ctg\left(\beta L\right)$$

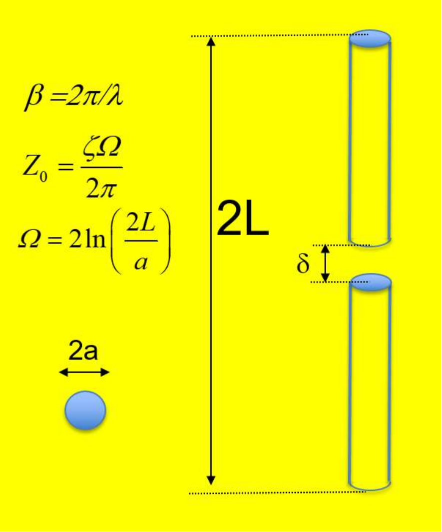
$$I\left(z\right) = I_0 \frac{\sin\left(\beta L - \beta\left|z\right|\right)}{\sin\left(\beta L\right)}$$

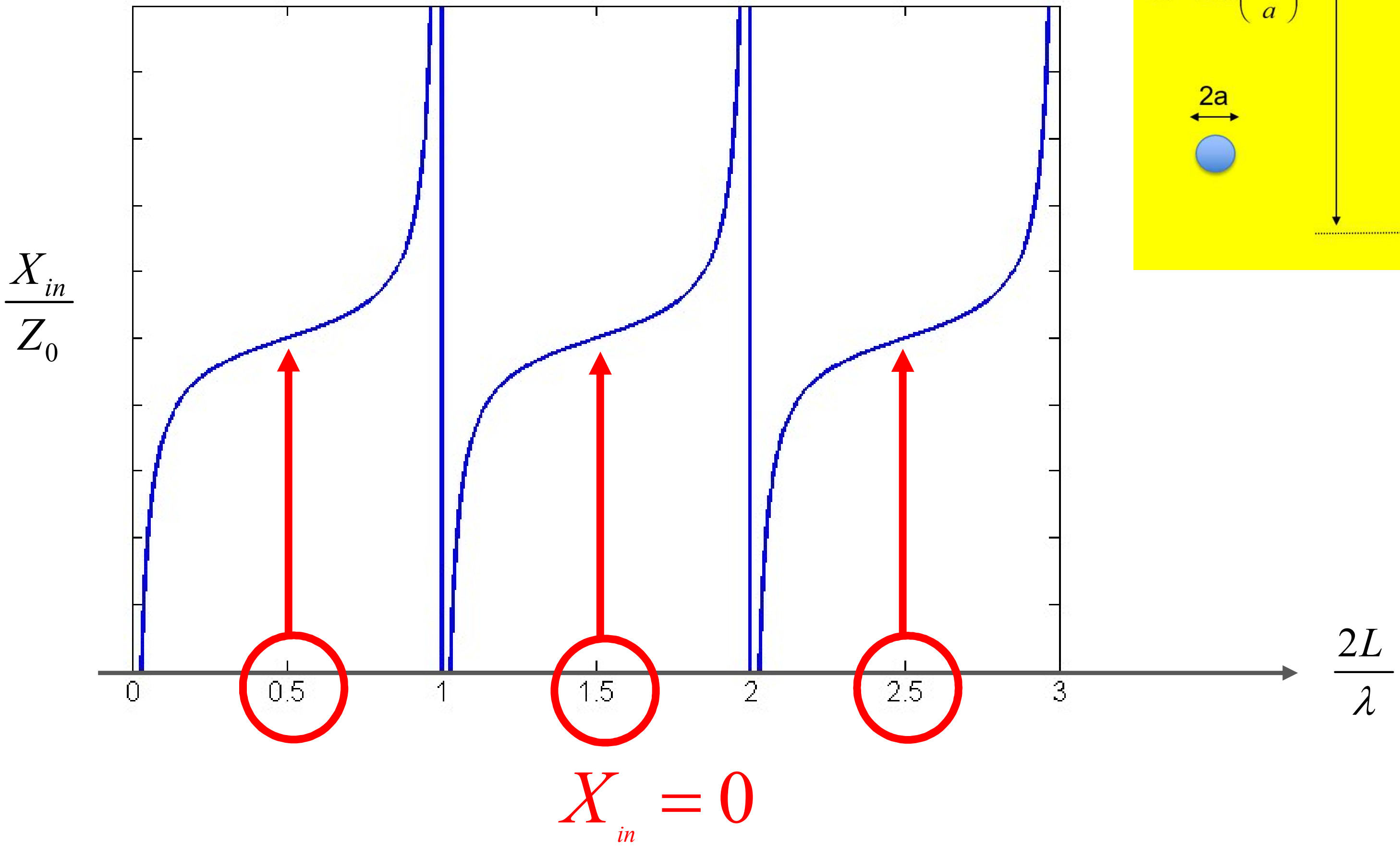


$$\Omega = 2\ln\left(\frac{2L}{a}\right)$$

Hallen Formulation

$$Z_{\text{in}} = -jZ_o ctg(\beta L) = -jZ_o ctg\left(\frac{2\pi}{\lambda} L\right) = jX_{\text{in}}$$





Wire antennas

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r}\left[\sin\vartheta F(\vartheta)\hat{i}_\vartheta\right]$$

$$\vec{\mathbf{l}}(\vartheta) = \sin\vartheta F(\vartheta)\hat{i}_\vartheta$$

$$F(\vartheta) = F(u)\Big|_{u=-\beta\cos\vartheta}$$

$$F(u) = \int_{-L}^{L} dz\, \tilde{I}(z) e^{-juz}$$

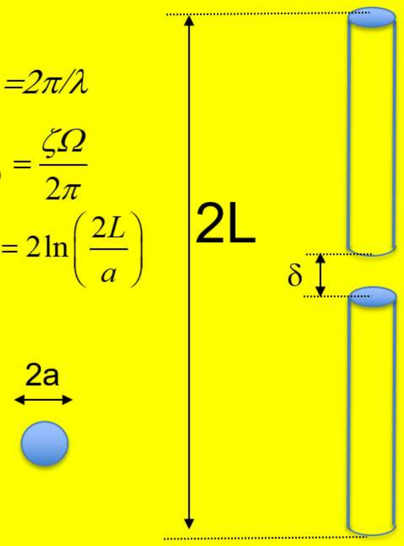
$$\tilde{I}(z) = \frac{I(z)}{I_0} = \frac{\sin(\beta L - \beta|z|)}{\sin(\beta L)}$$

$$X_{\text{in}} = -Z_o ctg(\beta L)$$

$$\beta = 2\pi/\lambda$$

$$Z_0 = \frac{\zeta\Omega}{2\pi}$$

$$\Omega = 2\ln\left(\frac{2L}{a}\right)$$



Short dipole

Short dipole

$$2L << \lambda$$

$$\vec{\mathbf{l}}(\vartheta) = L \sin\vartheta \, \hat{i}_\vartheta$$

$$D(\vartheta,\varphi) = \frac{3}{2}\sin^2\vartheta \qquad D_{\max} = 1.76 \text{ dB}$$

$$Z_{in} = R_{in} + jX_{\text{in}}$$

$$R_{rad} = \frac{2\pi}{3}\zeta\left(\frac{L}{\lambda}\right)^2$$

$$X_{\text{in}} = -Z_o ctg(\beta L)$$

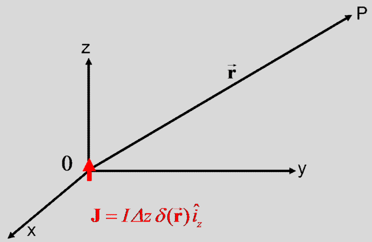
$\beta = 2\pi/\lambda$

$$Z_0 = \frac{\zeta\Omega}{2\pi}$$

$$\Omega = 2\ln\left(\frac{2L}{a}\right)$$

Elementary electrical dipole

$$\vec{\mathbf{l}}(\vartheta) = \Delta z \sin\vartheta \, \hat{i}_\vartheta$$

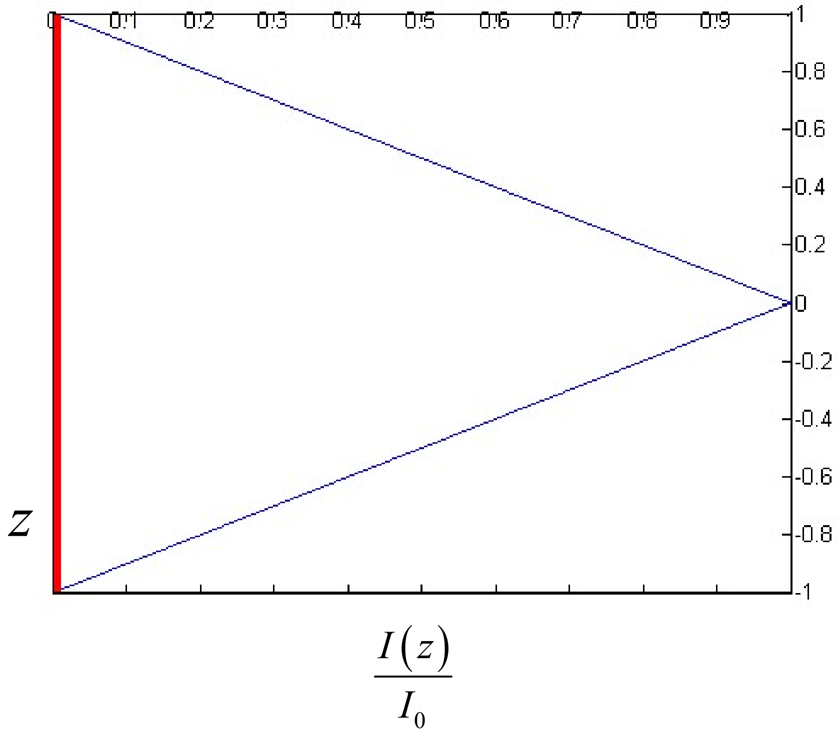


$$D(\vartheta,\varphi) = \frac{3}{2}\sin^2\vartheta \qquad D_{\max} = 1.76 \text{ dB}$$

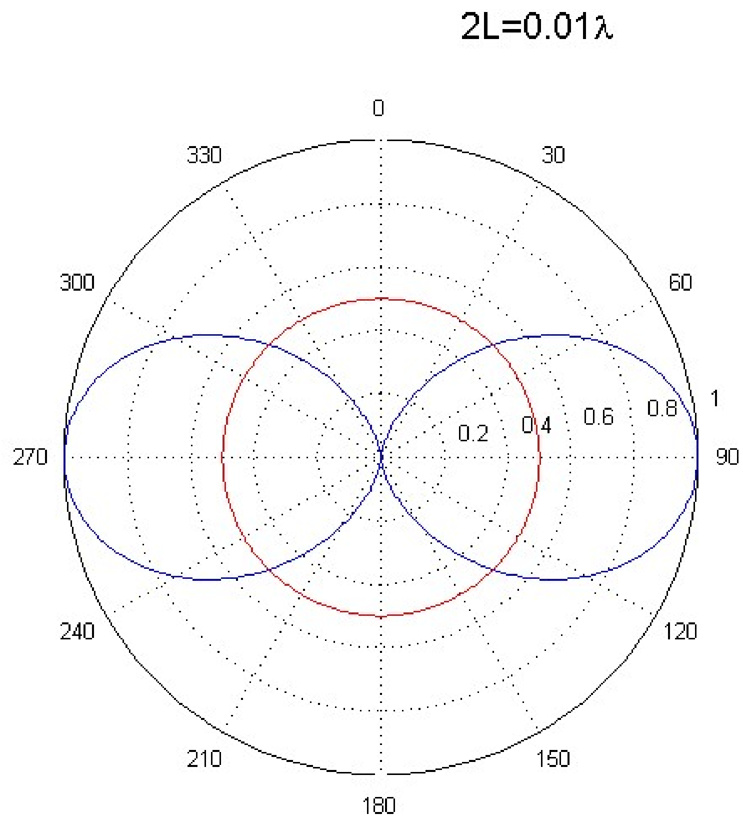
$$R_{rad} = \frac{2\pi}{3}\zeta\left(\frac{\Delta z}{\lambda}\right)^2$$

Short dipole

Current distribution

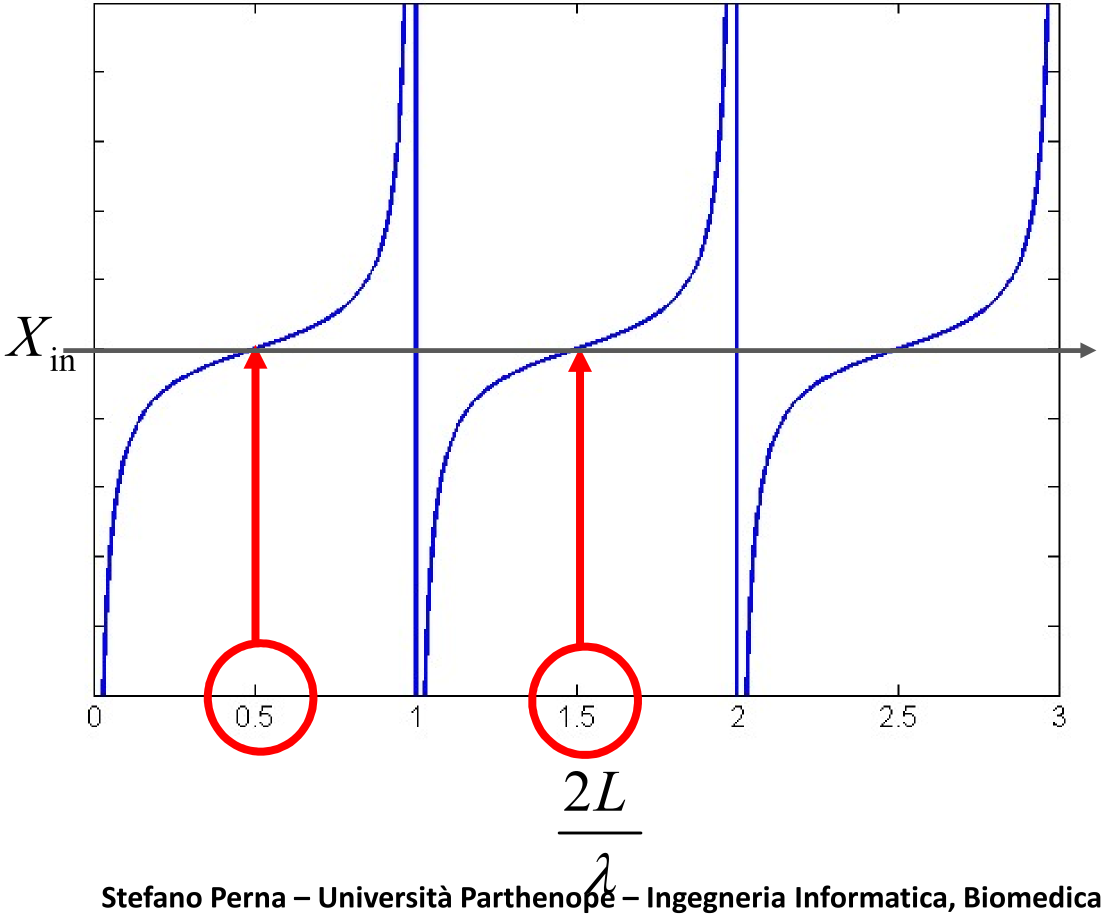


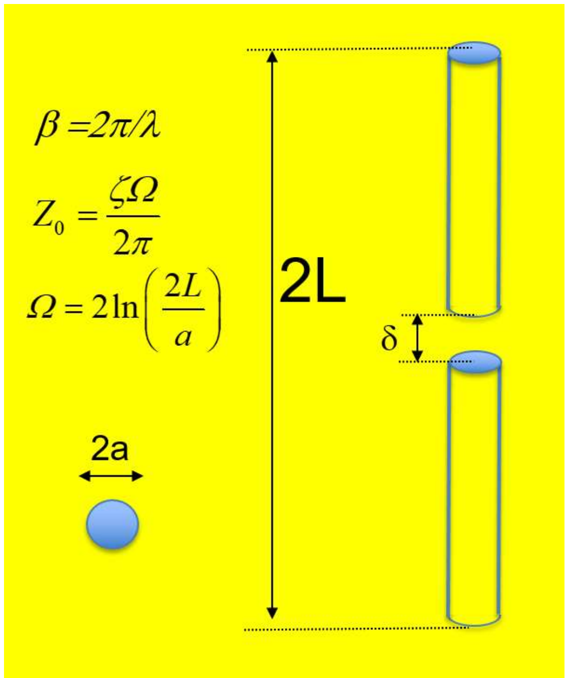
Power pattern
(vertical plane)



Wire antennas

λ/2 antenna & 3λ/2 antennas



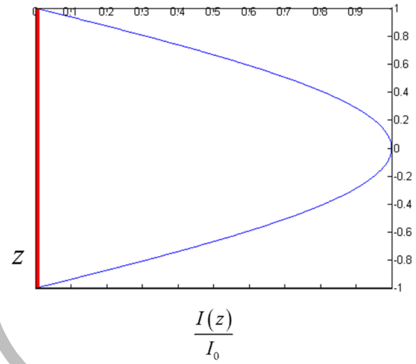


λ/2 vs. 3λ/2

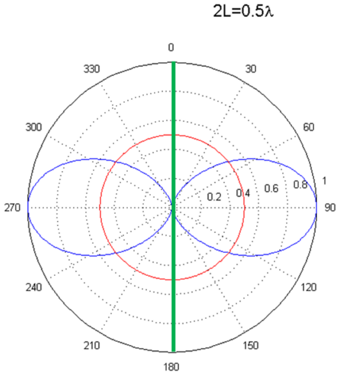
$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r} \sin\vartheta\, \hat{i}_\vartheta \int_{-l}^{l} dz \frac{I(z)}{I_0} \exp(j\beta z \cos\vartheta)$$

Half wavelength antenna

Current distribution

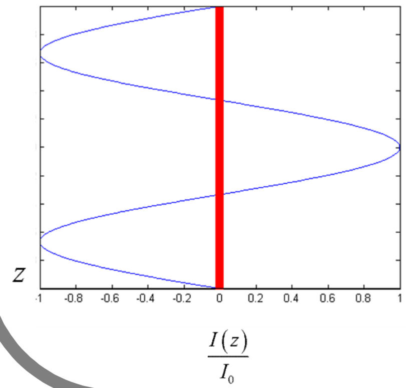


Power pattern (vertical plane)

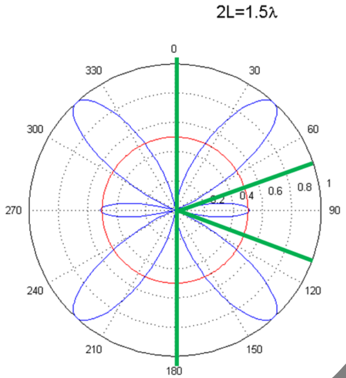


3/2 wavelength antenna

Current distribution

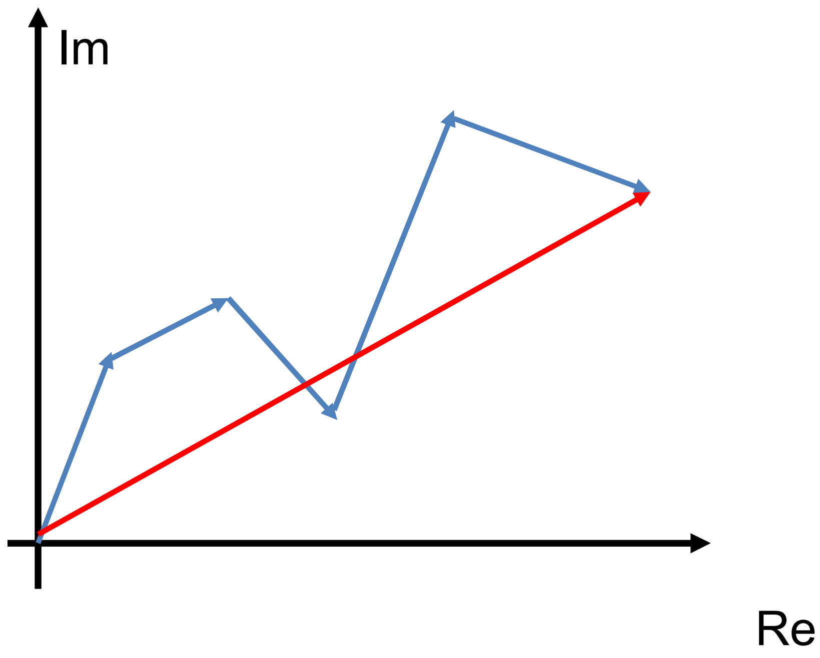


Power pattern (vertical plane)



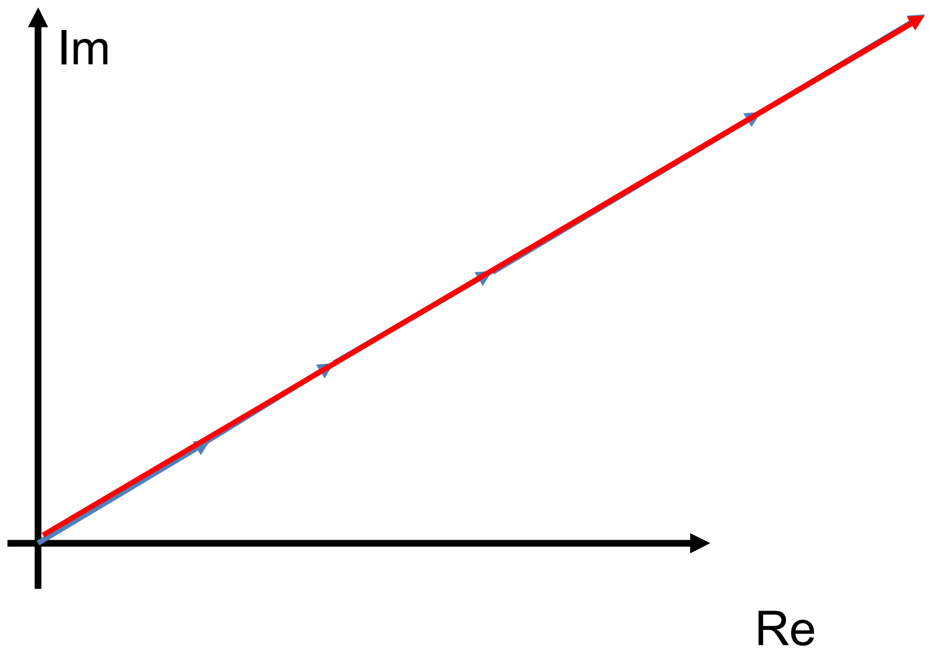
λ/2 vs. 3λ/2

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda}I_0\frac{\exp[-j\beta r]}{r}\sin\vartheta\,\hat{i}_\vartheta \boxed{\int_{-l}^{l} dz\frac{I(z)}{I_0}\exp(j\beta z\cos\vartheta)}$$



λ/2 vs. 3λ/2

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r} \sin\vartheta\, \hat{i}_\vartheta \int_{-l}^{l} dz \frac{I(z)}{I_0} \exp(j\beta z \cos\vartheta)$$



λ/2 vs. 3λ/2

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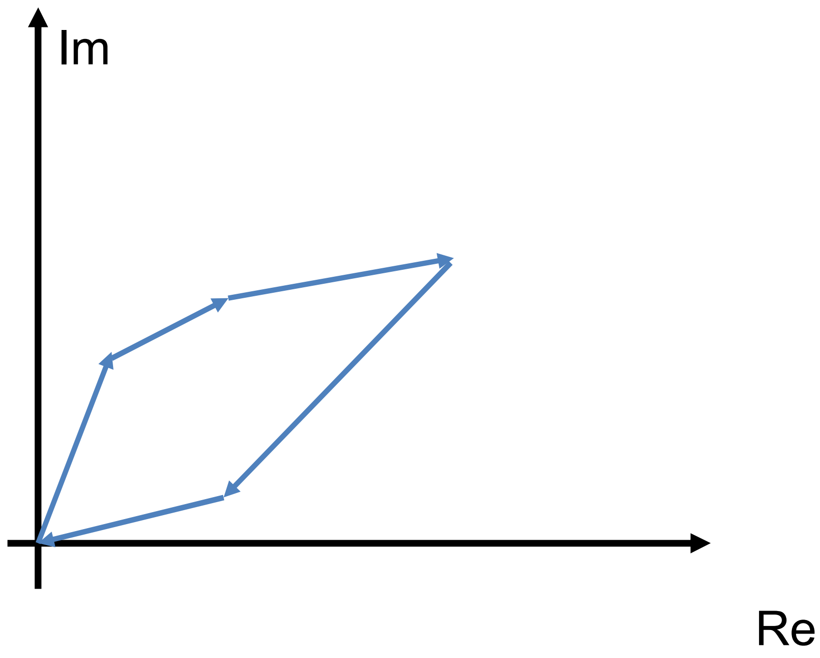
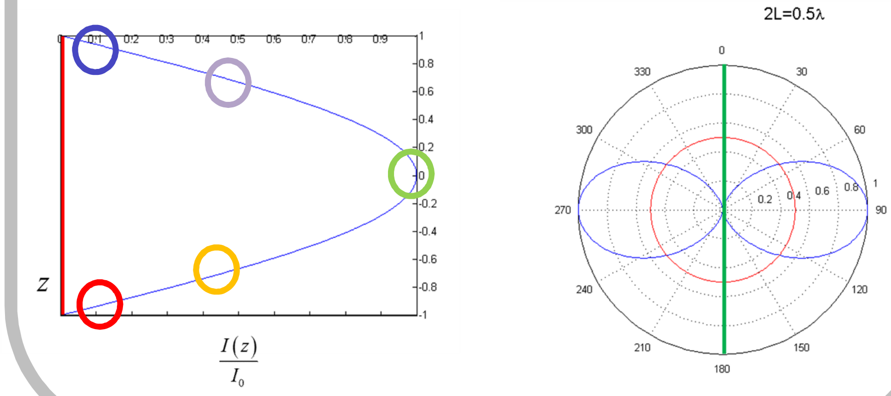


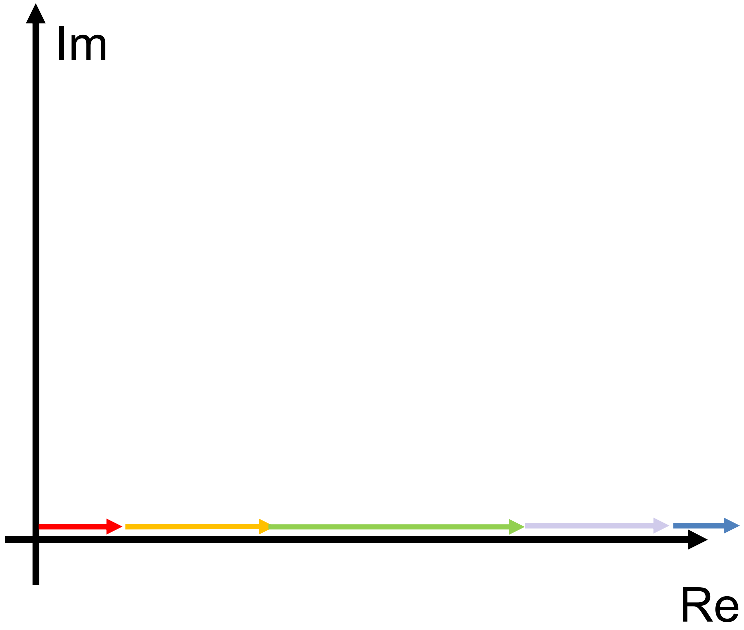
λ/2 vs. 3λ/2

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r} \sin\vartheta\, \hat{i}_\vartheta \int_{-l}^{l} dz \frac{I(z)}{I_0}$$

$\vartheta=\pi/2$

Half wavelength antenna



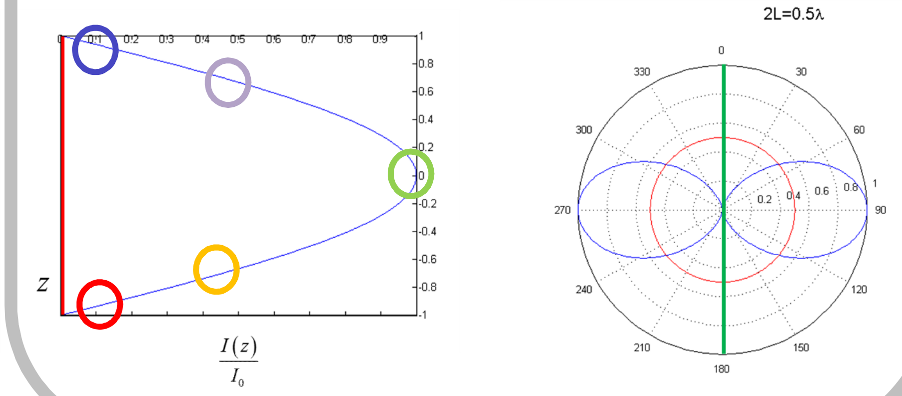


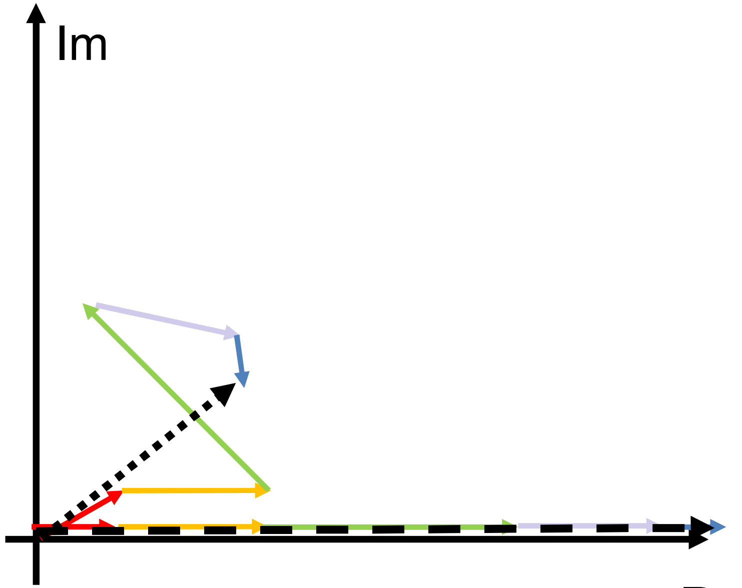
λ/2 vs. 3λ/2

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r} \sin\vartheta\, \hat{i}_\vartheta \int_{-l}^{l} dz \frac{I(z)}{I_0} \exp(j\beta z\cos\vartheta)$$

$\vartheta \neq \pi/2$

Half wavelength antenna





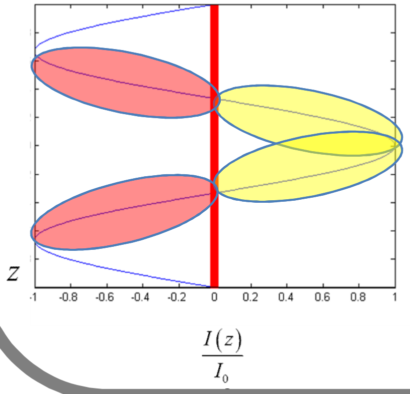
λ/2 vs. 3λ/2

$$\vec{\mathbf{E}} = j\frac{\zeta}{2\lambda} I_0 \frac{\exp[-j\beta r]}{r}\sin\vartheta\,\hat{i}_\vartheta \int_{-l}^{l} dz \frac{I(z)}{I_0}$$

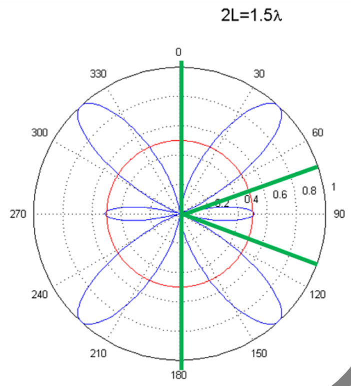
$\vartheta=\pi/2$

3/2 wavelength antenna

Current distribution



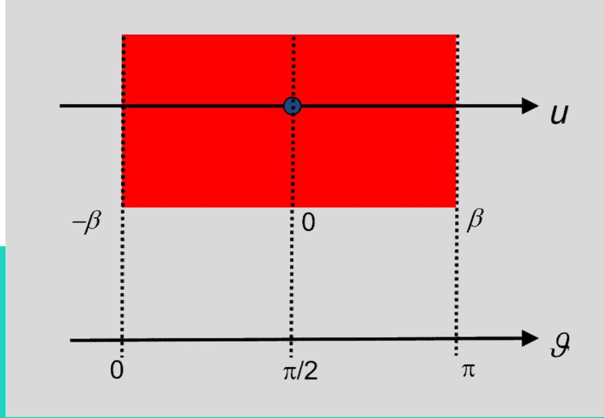
Power pattern (vertical plane)



Numerical examples

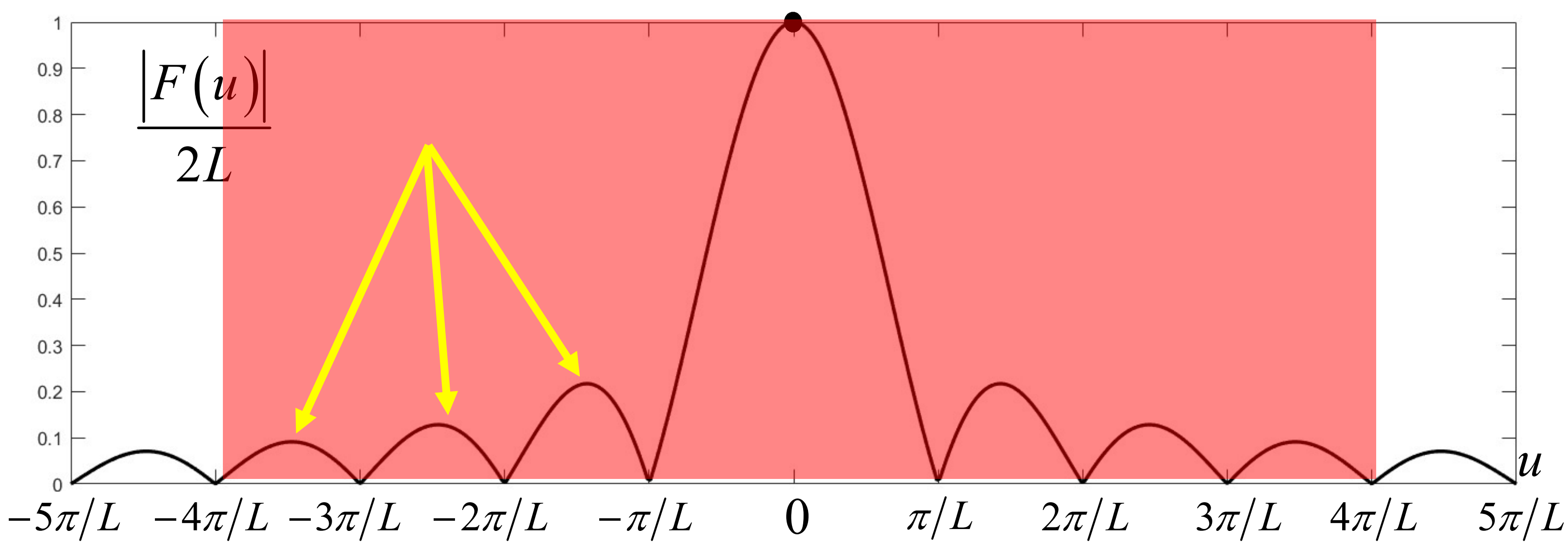
Wire antennas: an **ideal** case

$$F(u) = 2L\frac{\sin(uL)}{uL}$$



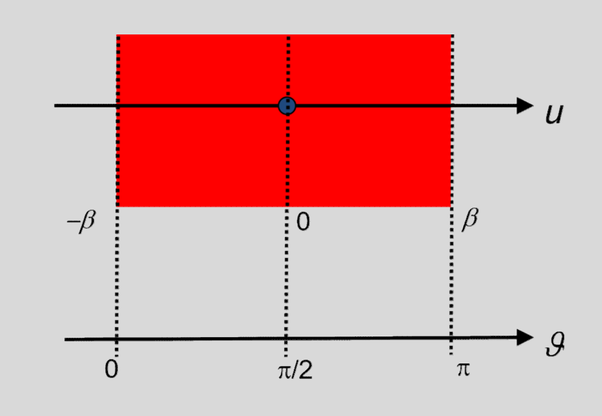
Exercise n.1

$$2L = 4\lambda \quad \Rightarrow \quad \lambda = \frac{L}{2} \quad \Rightarrow \quad \beta = \frac{2\pi}{\lambda} = \frac{4\pi}{L}$$



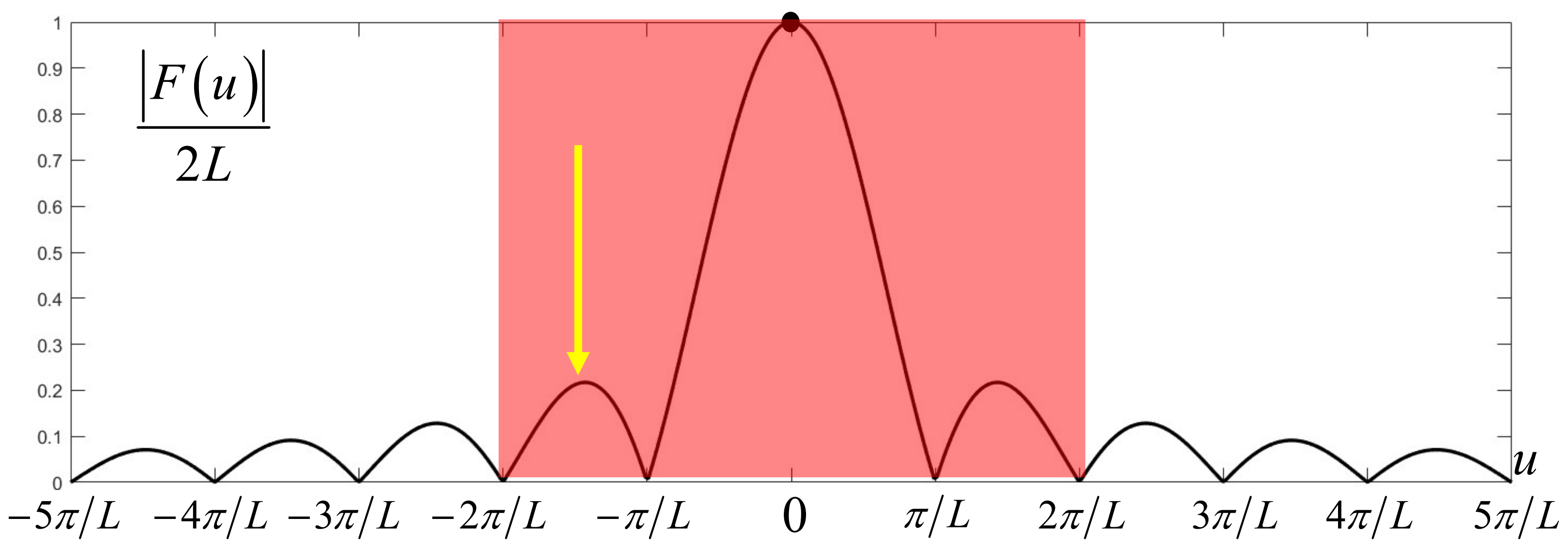
Wire antennas: an **ideal** case

$$F(u) = 2L\frac{\sin(uL)}{uL}$$



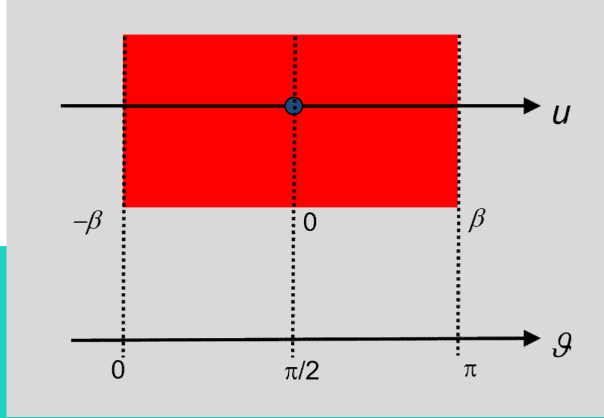
Exercise n.2

$$2L = 2\lambda \quad \Rightarrow \quad \lambda = L \quad \Rightarrow \quad \beta = \frac{2\pi}{\lambda} = \frac{2\pi}{L}$$



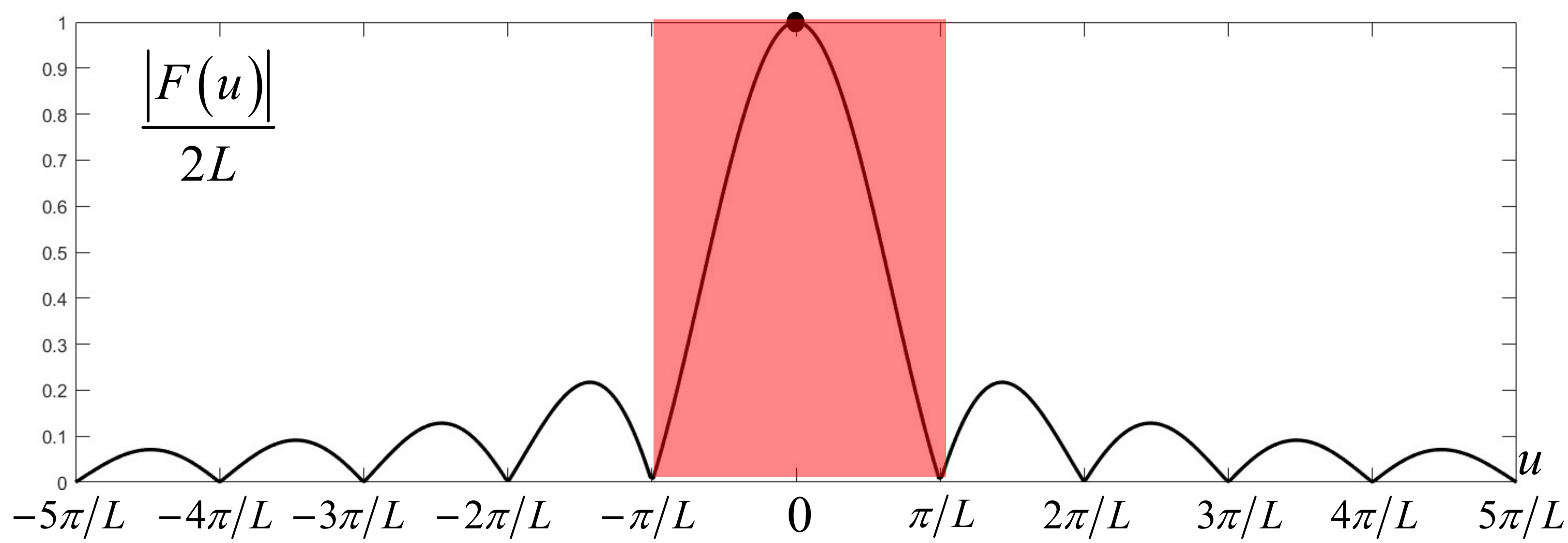
Wire antennas: an **ideal** case

$$F(u) = 2L\frac{\sin(uL)}{uL}$$



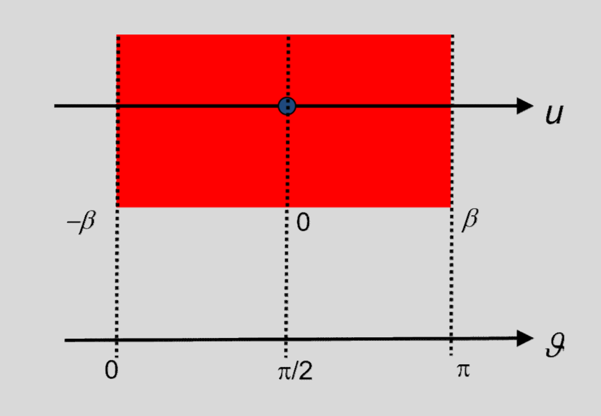
Exercise n.3

$$2L = \lambda \quad \Rightarrow \quad \beta = \frac{2\pi}{\lambda} = \frac{\pi}{L}$$



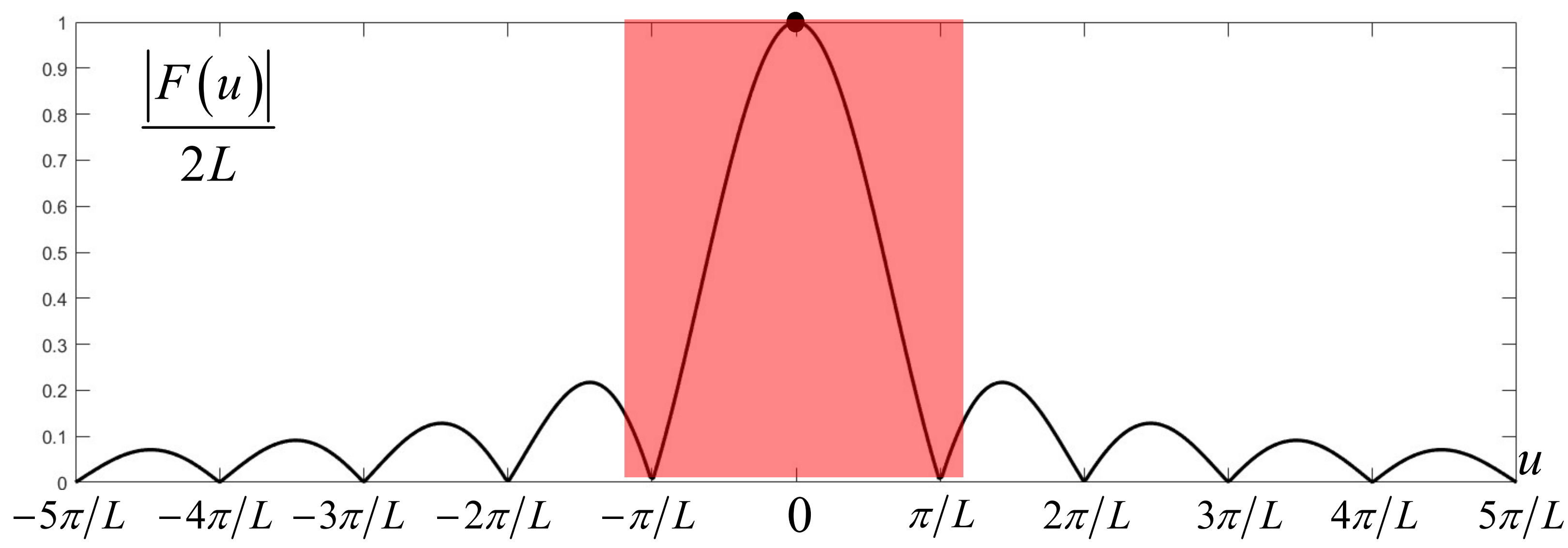
Wire antennas: an **ideal** case

$$F(u) = 2L\frac{\sin(uL)}{uL}$$



Exercise n.4

$$2L = 1.2\,\lambda \;\Rightarrow\; \lambda = \frac{2}{1.2}L \;\Rightarrow\; \beta = \frac{2\pi}{\lambda} = 1.2\frac{\pi}{L}$$



Wire antennas: the **real** case

Directivity