Telkom University

DTG3F3
Teknik Antena
dan propagasi

Antena Dipole dan Monopole

By : Dwi Andi Nurmantris

Varian Antena Dipole dan Monopole

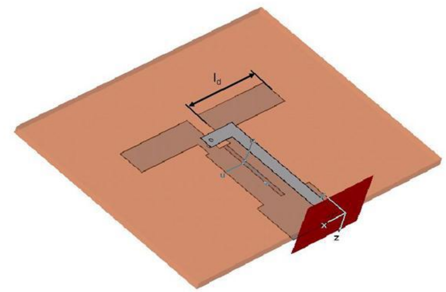
Materi di sadur dari buku
"ANTENNA THEORY
ANALYSIS AND DESIGN"
oleh Constantine A. Balanis
Dan
ANTENNAS
FROM THEORY TO PRACTICE
Oleh Yi Huang dan Kevin Boyle
Dan
Referensi yang lain

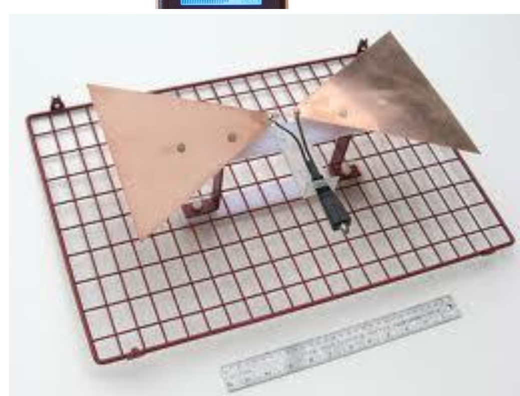
Varian Antena Dipole dan Monopole

Ada beberapa macam/varian Antenna Dipole antara lain :

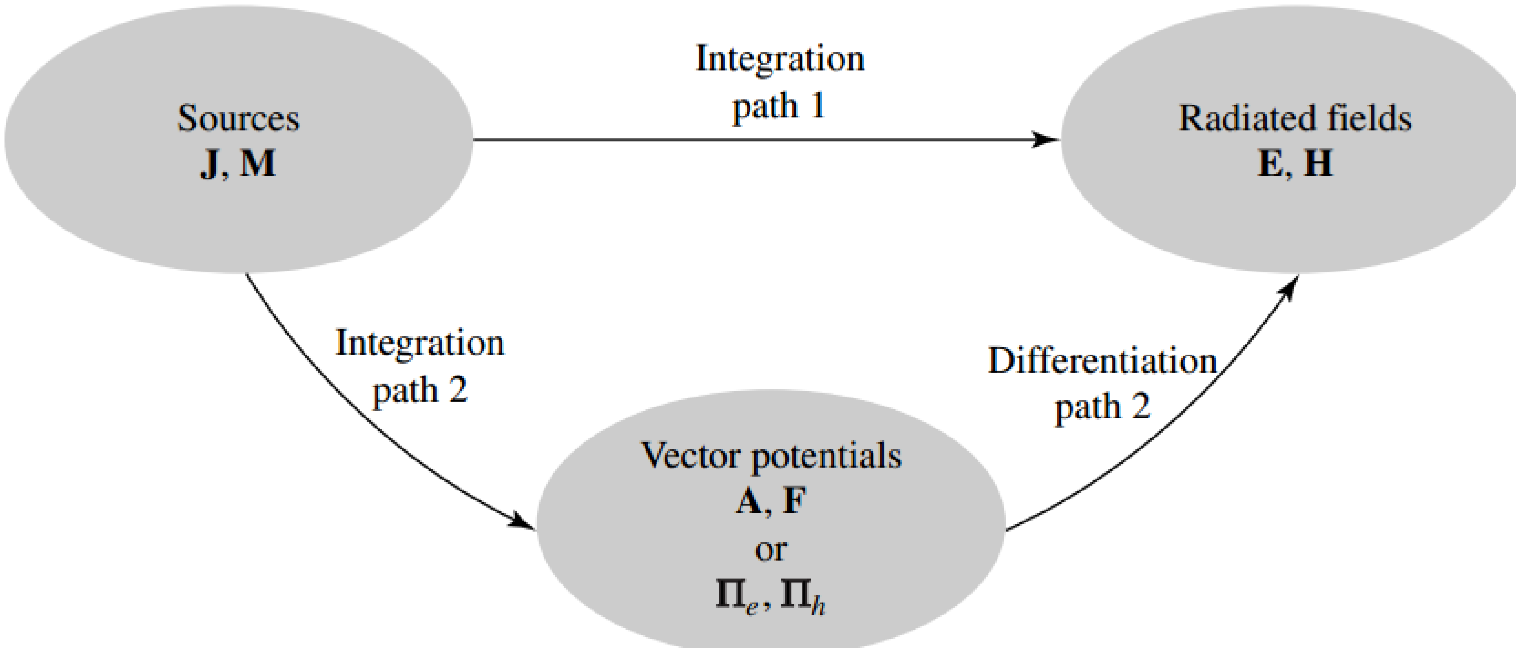
1. Hertzian Dipole/Infinitesimal Dipole
2. Short Dipole Antenna
3. Dipole **λ/2**
4. Antena Monopole
5. Antena Biconical
6. Cylindrical Antenna
7. Bow Tie Antenna
8. Folded Dipole Antena
9. Sleeve Dipole
10. Discone dan Conical Skirt Monopole
11. Printed Dipole

Dipole Antenna





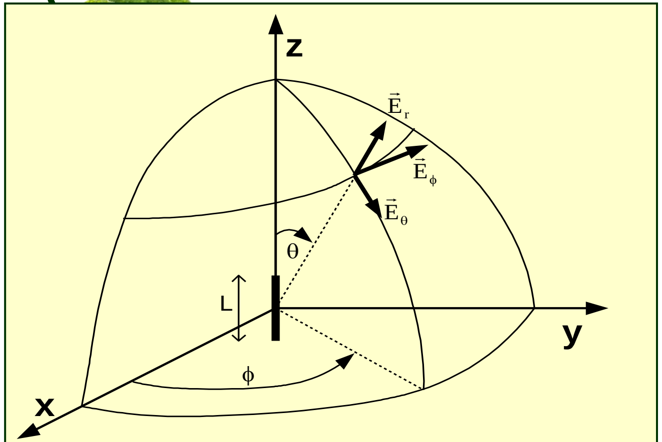
Analysis Step

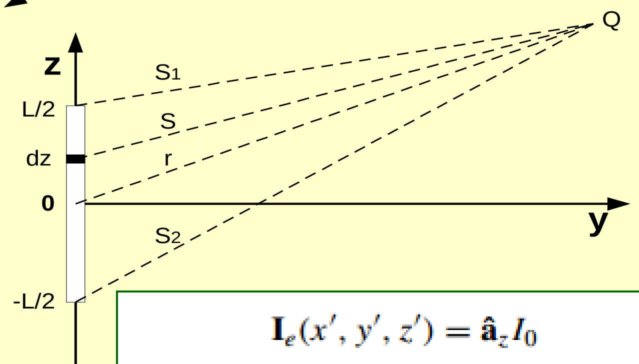


Block diagram for computing fields radiated by electric and magnetic sources.

Hertzian Dipole/Infinitesimal Dipole

- Suatu antena hertzian dipole, merupakan konduktor tipis **(d<<λ)** dengan panjang l sangat pendek bila dibandingkan dengan panjang gelombangnya **(l << λ)** biasanya **l ≤λ/50**
- GEM yang diradiasikan :





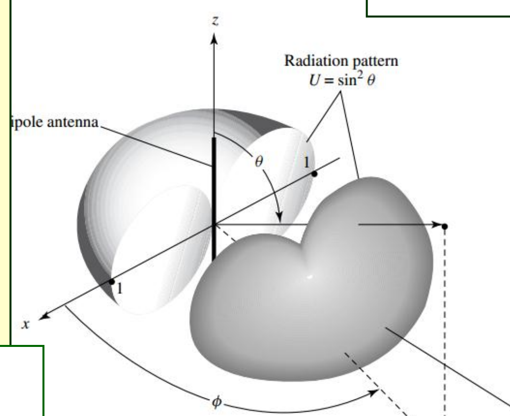
$$\mathbf{I}_e(x', y', z') = \hat{\mathbf{a}}_z I_0$$

Distribusi Medan Dekat

$$E_r = \frac{I_0 L \cos\theta}{2\pi\varepsilon}\left[\frac{1}{cr^2} + \frac{1}{j\omega r^3}\right] e^{j\omega\left(t - r/c\right)}$$

$$E_\theta = \frac{I_0 L \sin\theta}{4\pi\varepsilon}\left[\frac{j\omega}{c^2 r} + \frac{1}{cr^2} + \frac{1}{j\omega r^3}\right] e^{j\omega\left(t - r/c\right)}$$

$$H_\phi = \frac{I_0 L \sin\theta}{4\pi}\left[\frac{j\omega}{cr} + \frac{1}{r^2}\right] e^{j\omega\left(t - r/c\right)}$$



Syarat medan jauh (r >>)

$$E_\theta = \frac{j\omega I_0 L \sin\theta}{4\pi\varepsilon c^2 r} . e^{j\omega\left(t - r/c\right)}$$

$$H_\phi = \frac{j\omega I_0 L \sin\theta}{4\pi c r} . e^{j\omega\left(t - r/c\right)}$$

$$U = r^2\, W_{av} = \frac{\eta}{2}\left(\frac{k I_0 l}{4\pi}\right)^2 \sin^2\theta = \frac{r^2}{2\eta}|E_\theta(r, \theta, \phi)|^2$$

Hertzian Dipole/Infinitesimal Dipole

Radiation Resistance

$$R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2$$

Example 4.1

Find the radiation resistance of an infinitesimal dipole whose overall length is $l = \lambda/50$.

Solution: Using (4-19)

$$R_r = 80\pi^2\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{1}{50}\right)^2 = 0.316 \text{ ohms}$$

Since the radiation resistance of an infinitesimal dipole is about 0.3 ohms, it will present a very large mismatch when connected to practical transmission lines, many of which have characteristic impedances of 50 or 75 ohms. The reflection efficiency (e_r) and hence the overall efficiency (e_0) will be very small.

The reactance of an infinitesimal dipole is **capacitive**

Hertzian Dipole/Infinitesimal Dipole

Directivity dan Aem

$$D_0 = 4\pi \frac{U_{\max}}{P_{\text{rad}}} = \frac{3}{2}$$

$$A_{em} = \left(\frac{\lambda^2}{4\pi}\right) D_0 = \frac{3\lambda^2}{8\pi}$$

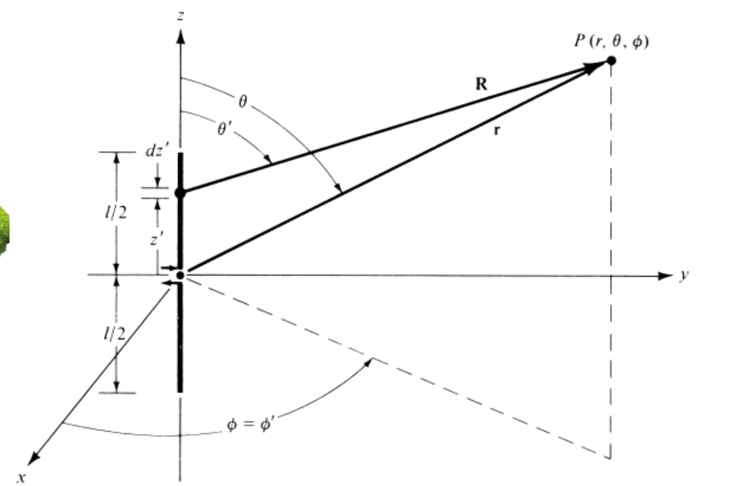
Hertzian Dipole/Infinitesimal Dipole

Ringkasan karakteristik Hertzian Dipole (l ≤λ/50)

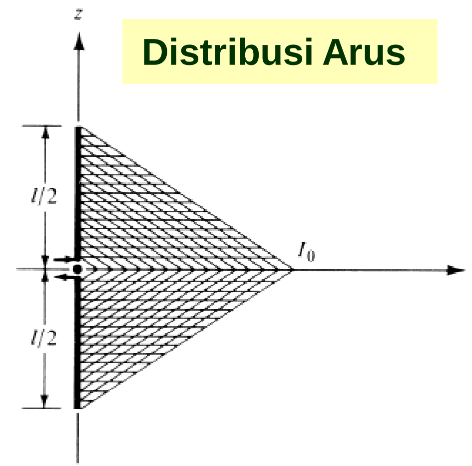
Normalized power pattern	$U = (E_{\theta n})^2 = C_0 \sin^2\theta$
Radiation resistance R_r	$R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2$
Input resistance R_{in}	$R_{in} = R_r = \eta\left(\frac{2\pi}{3}\right)\left(\frac{l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2$
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377 \text{ ohms}$
Directivity D_0	$D_0 = \frac{3}{2} = 1.761 \text{ dB}$
Maximum effective area A_{em}	$A_{em} = \frac{3\lambda^2}{8\pi}$
Vector effective length $\boldsymbol{\ell}_e$	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta l \sin\theta$ $\lvert\boldsymbol{\ell}_e\rvert_{\max} = \lambda$
Half-power beamwidth	$\text{HPBW} = 90^\circ$
Loss resistance R_L	$R_L = \frac{l}{P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{l}{2\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}}$

Dipole pendek

- Suatu antena dipole pendek, merupakan antena dipole yang memiliki panjang **λ/50<l≤λ/10**
- Asumsi diameter sangat kecil



Distribusi Arus



$$\mathbf{I}_e(x', y', z') = \begin{cases} \hat{\mathbf{a}}_z I_0\left(1 - \frac{2}{l}z'\right), & 0 \le z' \le l/2 \\ \hat{\mathbf{a}}_z I_0\left(1 + \frac{2}{l}z'\right), & -l/2 \le z' \le 0 \end{cases}$$

- GEM yang dipancarkan

$$\left.\begin{aligned} E_\theta &\simeq j\eta \frac{kI_0 l e^{-jkr}}{8\pi r}\sin\theta \\ E_r &\simeq E_\phi = H_r = H_\theta = 0 \\ H_\phi &\simeq j\frac{kI_0 l e^{-jkr}}{8\pi r}\sin\theta \end{aligned}\right\} \quad kr \gg 1$$

Dipole pendek

Ringkasan karakteristik Dipole Pendek (λ/50<l≤λ/10)

Parameter	Formula
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms
Directivity D_0	$D_0 = \frac{3}{2} = 1.761$ dB
Maximum effective area A_{em}	$A_{em} = \frac{3\lambda^2}{8\pi}$
Vector effective length $\boldsymbol{\ell}_e$	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \frac{l}{2} \sin\theta$ $\lvert\boldsymbol{\ell}_e\rvert_{\max} = \frac{l}{2}$
Half-power beamwidth	HPBW = 90°
Normalized power pattern	$U = (E_{\theta n})^2 = C_1 \sin^2\theta$
Radiation resistance R_r	$R_r = 20\pi^2 \left(\frac{l}{\lambda}\right)^2$
Input resistance R_{in}	$R_{in} = R_r = 20\pi^2 \left(\frac{l}{\lambda}\right)^2$

Finite Length Dipole

- Suatu antena dipole yang memiliki panjang sembarang
- Asumsi diameter sangat kecil

Distribusi Arus

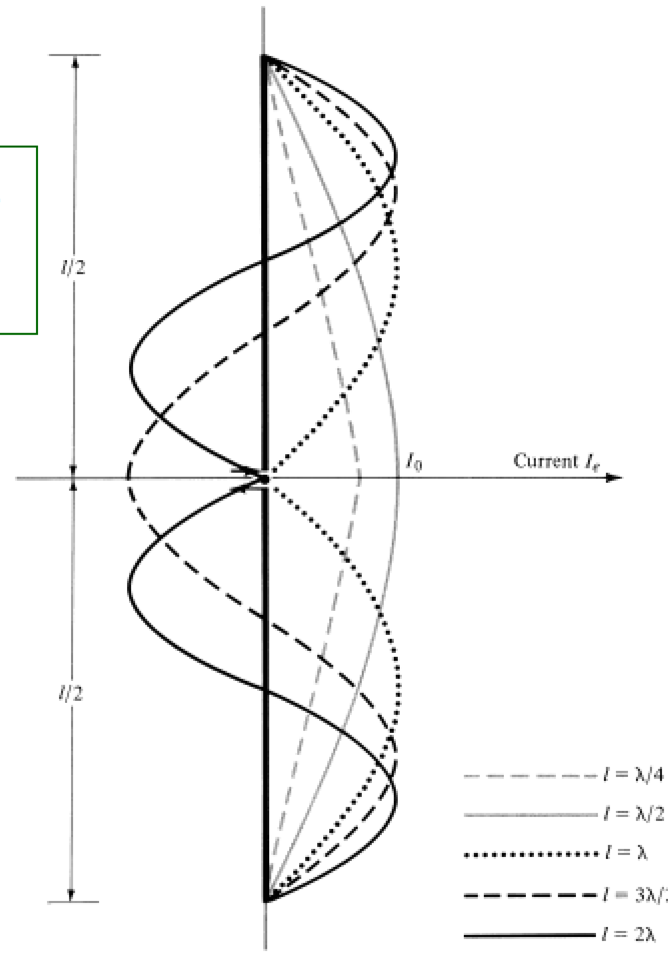
$$\mathbf{I}_e(x'=0, y'=0, z') = \begin{cases} \hat{\mathbf{a}}_z I_0 \sin\left[k\left(\frac{l}{2} - z'\right)\right], & 0 \le z' \le l/2 \\ \hat{\mathbf{a}}_z I_0 \sin\left[k\left(\frac{l}{2} + z'\right)\right], & -l/2 \le z' \le 0 \end{cases}$$

- GEM yang diradiasikan

$$E_\theta \simeq j\eta \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta}\right]$$

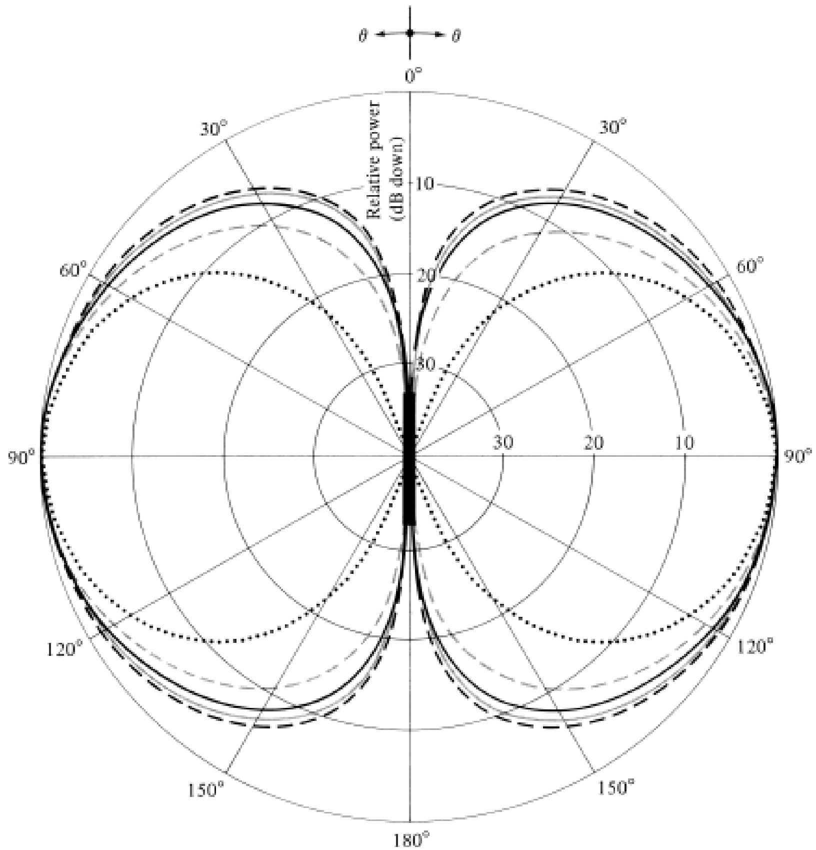
$$H_\phi \simeq \frac{E_\theta}{\eta} \simeq j\frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta}\right]$$

$$U = r^2\, W_{av} = \eta\frac{|I_0|^2}{8\pi^2}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta}\right]^2$$

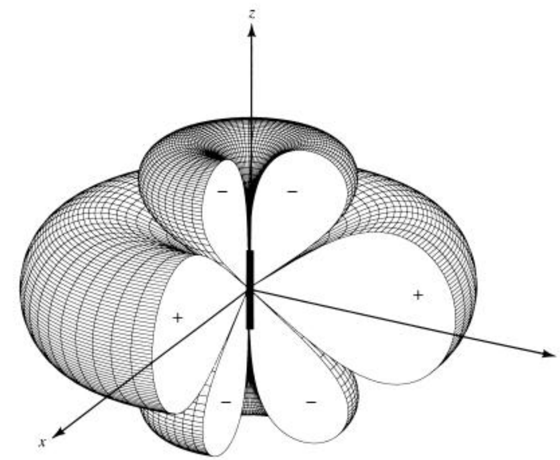


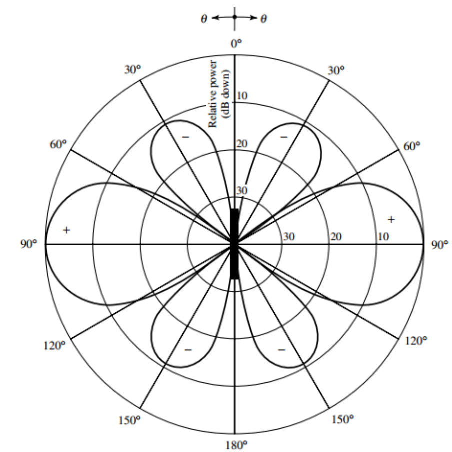
Finite Length Dipole

Radiation Pattern



— — — —	$l = \lambda/50$	$l = \lambda/50$	3-dB beamwidth = 90°
———— (grey)	$l = \lambda/4$	$l = \lambda/4$	3-dB beamwidth = 87°
————	$l = \lambda/2$	$l = \lambda/2$	3-dB beamwidth = 78°
– – – – –	$l = 3\lambda/4$	$l = 3\lambda/4$	3-dB beamwidth = 64°
··········	$l = \lambda$	$l = \lambda$	3-dB beamwidth = 47.8°





Contoh untuk antena dipole l =1.25λ

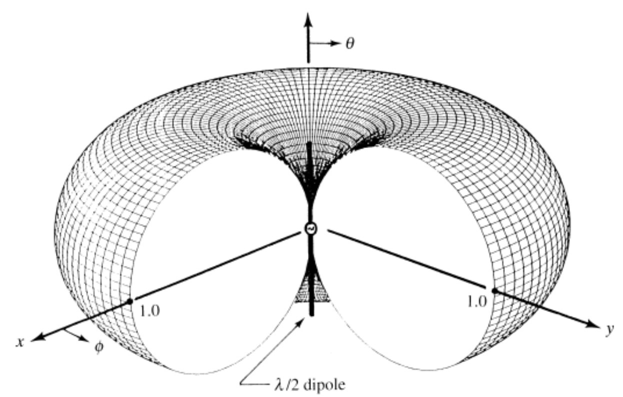
Dipole λ/2

- ❑ Suatu antena dipole yang panjangnya ***λ/2***
- ❑ Kelebihan :
  - Pola radiasi Omni Directinal
  - Directivitasnya 2,14 dB→ cukup besar bila dibanding dipole pendek
  - Panjang relatif kecil
  - Impedansi input tidak sensitif terhadap radius dipole
  - Impedansi 73+ J42,5 Ω → mendekati match dengan 50 atau 75 Ω saltran
  - Frequensi kerja/resonansi terjadi didekat panjang antena ***λ/2***
- ❑ GEM yang diradiasikan :

$$E_\theta \simeq j\eta \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

$$H_\phi \simeq j \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

$$U = r^2\, W_{av} = \eta \frac{|I_0|^2}{8\pi^2}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]^2 \simeq \eta \frac{|I_0|^2}{8\pi^2}\sin^3\theta$$



Dipole λ/2

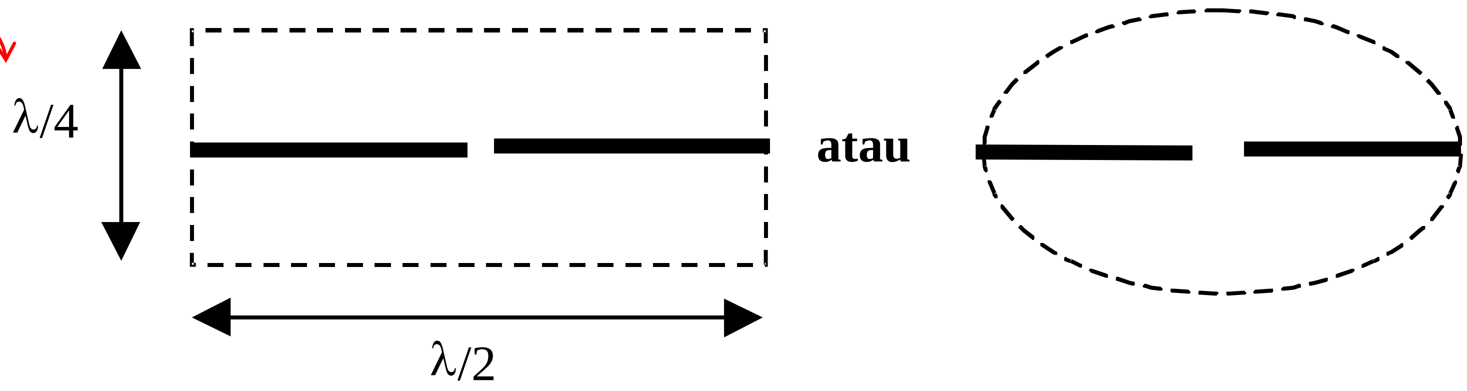
Directivity, Aem, dan impedansi terminal

$$D_0 = 4\pi \frac{U_{\max}}{P_{\text{rad}}} = 4\pi \frac{U|_{\theta=\pi/2}}{P_{\text{rad}}} = \frac{4}{C_{in}(2\pi)} = \frac{4}{2.435} \simeq 1.643$$

$$A_{em} = \frac{\lambda^2}{4\pi} D_0 = \frac{\lambda^2}{4\pi}(1.643) \simeq 0.13\lambda^2$$

$$Z_{in} = 73 + j42.5$$

Untuk menghilangkan bagian imajiner biasanya panjang dipole dikurangi sampai bagian imajiner = 0 → biasanya dipole dipotong hingga panjangnya tinggal 0,47λ-0,48λ



Dipole λ/2

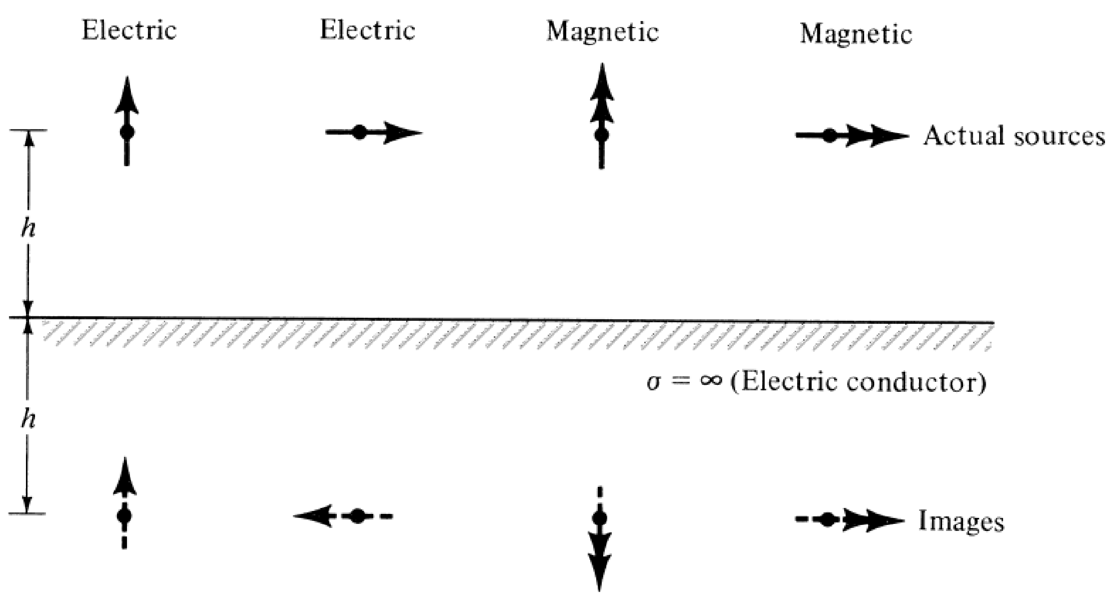
Ringkasan karakteristik Dipole λ/2

Parameter	Formula
Loss resistance R_L	$R_L = \frac{l}{2P}\sqrt{\frac{\omega\mu_0}{2\sigma}} = \frac{l}{4\pi b}\sqrt{\frac{\omega\mu_0}{2\sigma}}$
Normalized power pattern	$U = (E_{\theta n})^2 = C_2 \left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \right]^2 \simeq C_2 \sin^3\theta$
Radiation resistance R_r	$R_r = \frac{\eta}{4\pi} C_{in}(2\pi) \simeq 73$ ohms
Input resistance R_{in}	$R_{in} = R_r = \frac{\eta}{4\pi} C_{in}(2\pi) \simeq 73$ ohms
Input impedance Z_{in}	$Z_{in} = 73 + j42.5$
Wave impedance Z_w	$Z_w = \frac{E_\theta}{H_\phi} \simeq \eta = 377$ ohms
Directivity D_0	$D_0 = \frac{4}{C_{in}(2\pi)} \simeq 1.643 = 2.156$ dB
Vector effective length $\boldsymbol{\ell}_e$	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \frac{\lambda}{\pi} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$ $\lvert\boldsymbol{\ell}_e\rvert_{\max} = \frac{\lambda}{\pi} = 0.3183\lambda$
Half-power beamwidth	HPBW $= 78^\circ$

Monopole λ/4

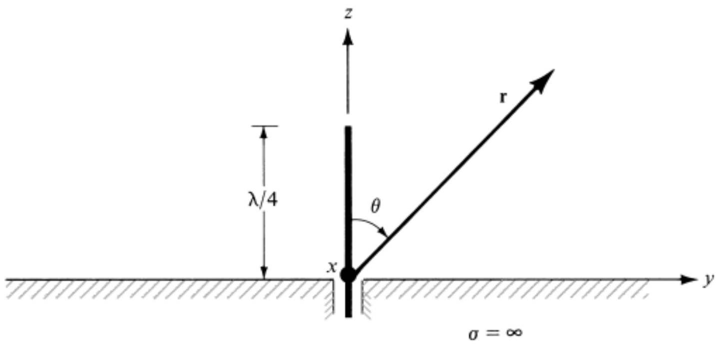
IMAGE THEORY

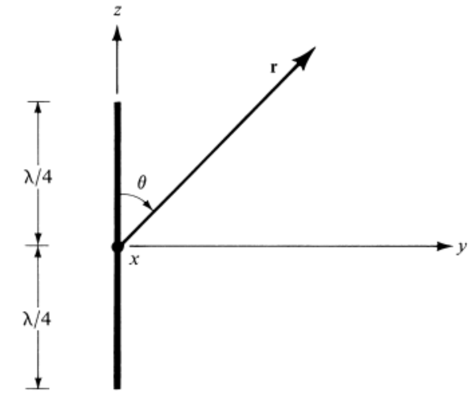
- Image theory menyatakan bahwa jika ada suatu sumber/source/antena didekat suatu konduktor datar yang luasnya tak terbatas (*infinite plane konduktor*), maka sebuah sumber virtual (image) seolah-olah muncul dan untuk keperluan analisis perlu dikombinasikan dengan real source.



Monopole λ/4

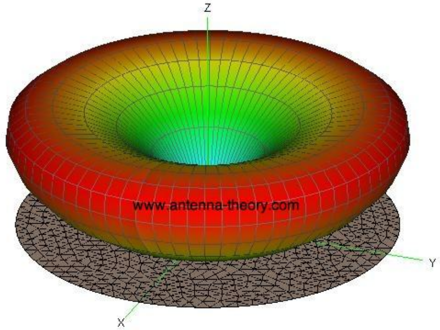
- Suatu antena monopole **λ/4** diatas groundplane
- Kelebihan :
  - Dimensinya lebih kecil dari antena dipole **λ/2**
  - Direktivitasnya 2 kali lebih besar dari dipole **λ/2**
  - Impedansinya ½ dari impedansi dipole **λ/2**





Equivalent of λ/4 monopole on infinite electric conductor

- GEM yang diradiasikan :



Monopole λ/4

Directivity dan impedansi terminal

$D_0 = 2.D_{dipole} = 5{,}167$ dB

$$Z_{im}\ \text{(monopole)} = \frac{1}{2} Z_{im}\ \text{(dipole)} = \frac{1}{2}[73 + j42.5] = 36.5 + j21.25$$

CATATAN : Nilai-nilai pendekatan diatas dengan asumsi bahwa groundplane terbuat dari konduktor sempurna dan luasnya tak terhingga

Jika groundplane tidak konduktor sempurna dan finite maka :

- Ada radiasi yang bocor ke bawah yang menimbulkan sidelobe dan backlobe
- Bagian tepi dari groundplane akan meradiasikan gelombang
- Direktivitas akan berkurang
- Impedansi input bisa berubah
- Jika groundplane tidak terlalu besar bisa-bisa groundplane menjadi radiator

Diameter Groundplane setidaknya lebih besar dari λ/2

Monopole λ/4

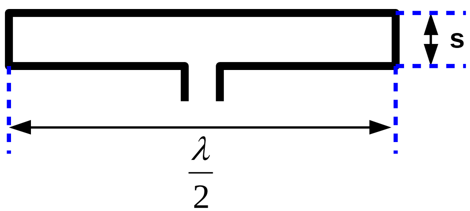
Ringkasan karakteristik Monopole λ/4

Parameter	Formula
Normalized power pattern	$U = (E_{\theta n})^2 = C_2 \left[\dfrac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \right]^2 \simeq C_2 \sin^3\theta$
Radiation resistance R_r	$R_r = \dfrac{\eta}{8\pi} C_{in}(2\pi) \simeq 36.5 \text{ ohms}$
Input resistance R_{in}	$R_{in} = R_r = \dfrac{\eta}{8\pi} C_{in}(2\pi) \simeq 36.5 \text{ ohms}$
Input impedance Z_{in}	$Z_{in} = 36.5 + j21.25$
Wave impedance Z_w	$Z_w = \dfrac{E_\theta}{H_\phi} \simeq \eta = 377 \text{ ohms}$
Directivity D_0	$D_0 = 3.286 = 5.167 \text{ dB}$
Vector effective length $\boldsymbol{\ell}_e$	$\boldsymbol{\ell}_e = -\hat{\mathbf{a}}_\theta \dfrac{\lambda}{\pi} \cos\left(\dfrac{\pi}{2}\cos\theta\right)$ $\lvert\boldsymbol{\ell}_e\rvert_{\max} = \dfrac{\lambda}{\pi} = 0.3183\lambda$

Folded Dipole

- Folded Dipole digunakan untuk menaikkan *resistance radiation.*
- *Resistance radiation* yang besar bisanya diperlukan untuk keperluan matching impedance dengan saluran transmisi yang memiliki impedansi karakteristik besar seperti saluran dua kawat (Z0≈300Ω)

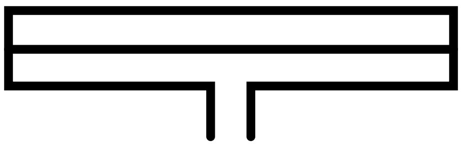
- **Dipole Lipat 2**



$$Z_T = \frac{V}{I_1} = N^2 Z_{11}$$

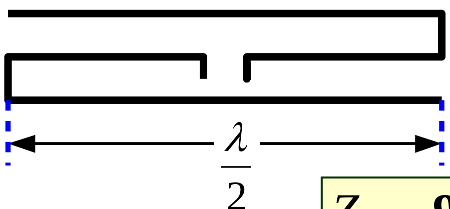
$$Z_T = \frac{V}{I_1} = 4Z_{11}$$

- **Dipole Lipat 3**

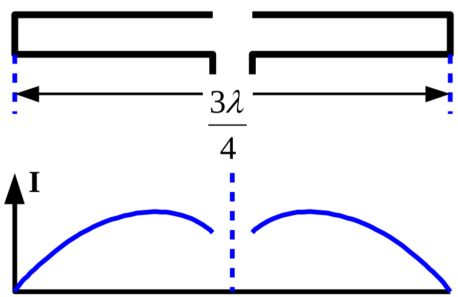


$$Z_T = 3^2 Z_{11} = 9 \times 70 = \mathbf{630\ \Omega}$$

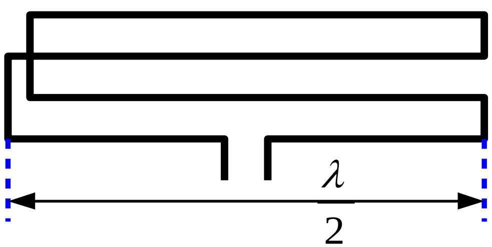
- **Lipatan Yang Lain**



$$Z_T = \mathbf{900\ \Omega}$$



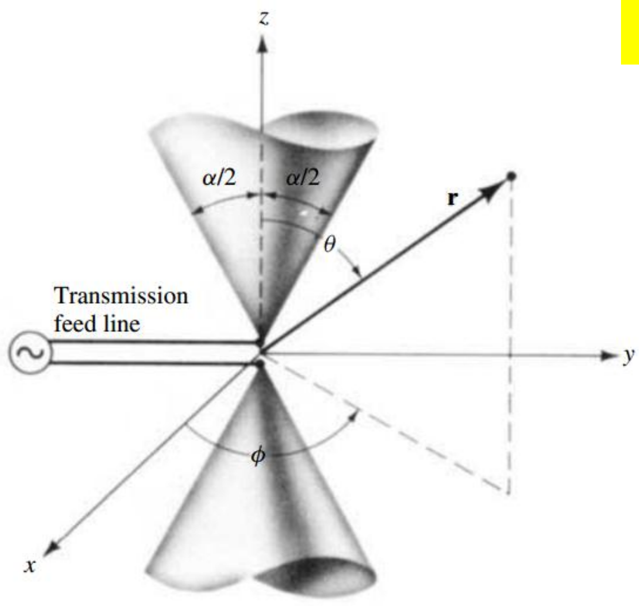
$$Z_T = \mathbf{450\ \Omega}$$



$$Z_T = \mathbf{1400\ \Omega}$$

Broadband Dipole

CONICAL UNIPOLE DAN BICONICAL ANTENA



Pola Radiasi dan impedansi terminal

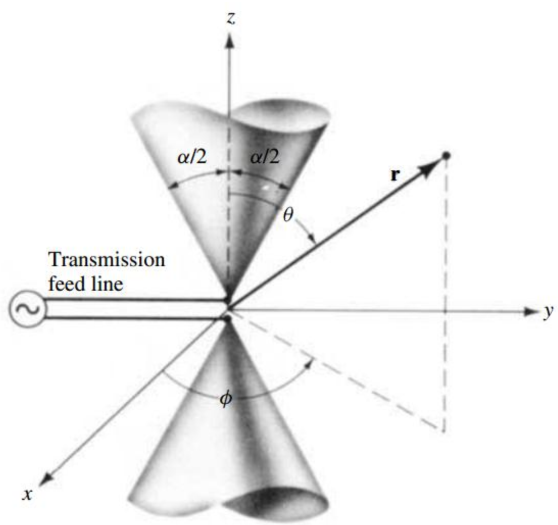
Pola radiasi dan impedansi antena conical dilaporkan pada jurnal berikut :

1. C. H. Papas and R. King, “Radiation from Wide-Angle Conical Antennas Fed by a Coaxial Line,”Proc. IRE, Vol. 39, p. 1269, November 1949.
2. G. H. Brown and O. M. Woodward Jr., “Experimentally Determined Radiation Characteristics of Conical and Triangular Antennas,” RCA Rev., Vol. 13, No. 4, p. 425, December 1952.

Antena Biconic sering digunakan pada range frekuensi VHF (30 – 300 MHz) dan UHF (300 MHz – 3 GHz)

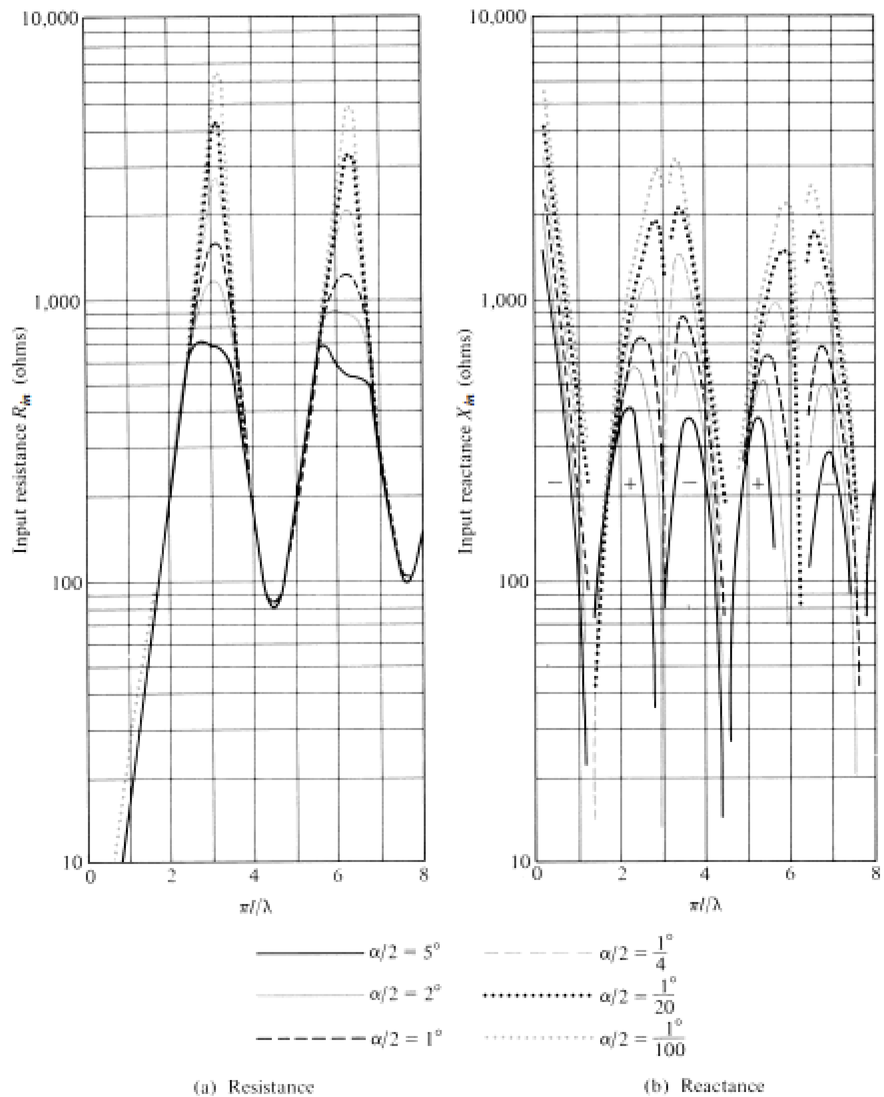
Broadband Dipole

BICONICAL ANTENA



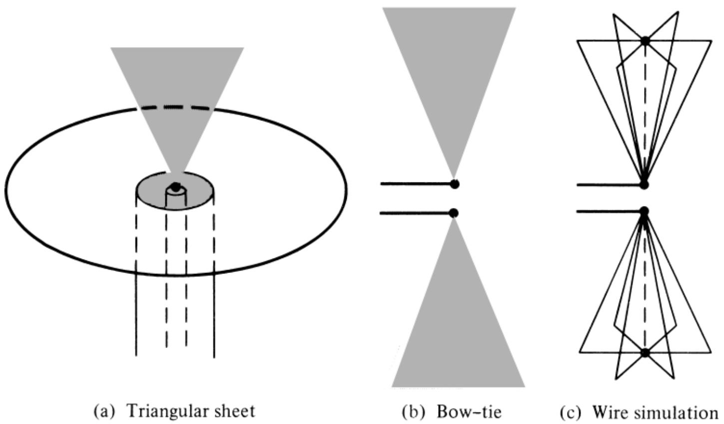
Dari grafik disamping menunjukkan bahwa semakin besar sudut conical maka bandwidth semakin besar

R. C. Johnson and H. Jasik (eds.), Antenna Engineering Handbook, McGraw-Hill, New York, 1984, Chapter 4



Broadband Dipole

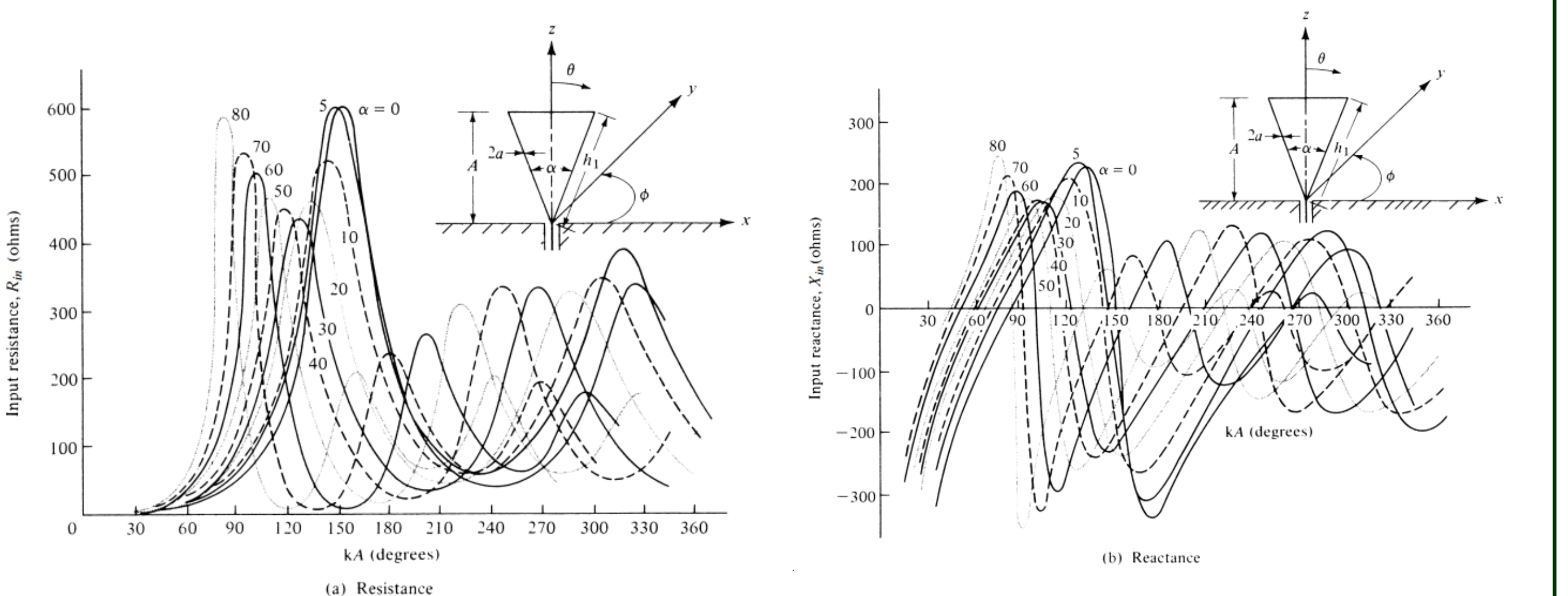
Triangular sheet & Bow-tie antenna



- Kekurangan utama dari antena conical adalah strukturnya yang pejal atau berongga sehingga dalam beberapa aplikasi tidak praktis. Maka sering penyederhanaan bentuk dasar conical dilakukan dengan pendekatan antena **triangular sheet dan Bow-tie**
- Triangular sheet dan bow-tie dibuat dari lempengan/lembaran konduktor, tetapi bisa dibuat juga dengan kawat tembaga membentuk triangular atau bow-tie di bagian tepi (**triangular dan bow-tie wire**)
- Dari hasil pengukuran ternyata antena bowtie atau triangular wire memiliki karakteristik **narrow band**

Broadband Dipole

Triangular sheet & Bow-tie antenna



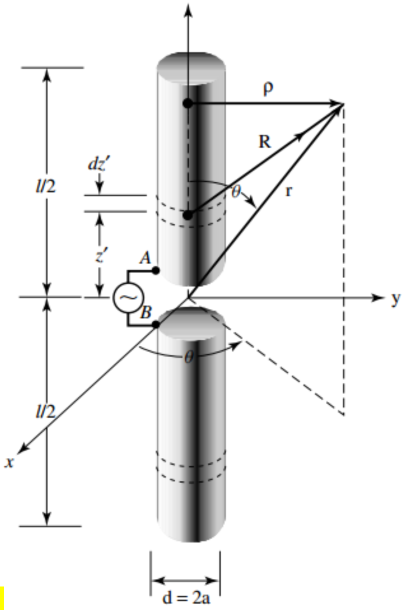
C. E. Smith, C. M. Butler, and K. R. Umashankar, "Characteristics of a Wire Biconical Antenna,"Microwave J., pp. 37 – 40, September 1979

Grafik diatas menunjukkan wire triangular dan wire bow-tie memiliki karakteristik narrow band

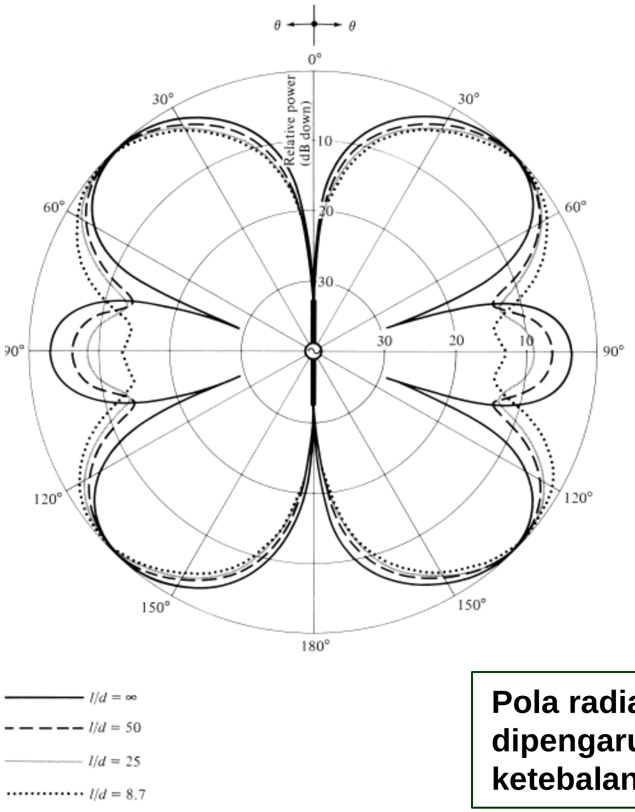
Broadband Dipole

CYLINDRICAL DIPOLE

- Cylindrical dipole bisa dipandang kasus khusus dari biconical antena dengan sudut conic = 0º



Pola Radiasi



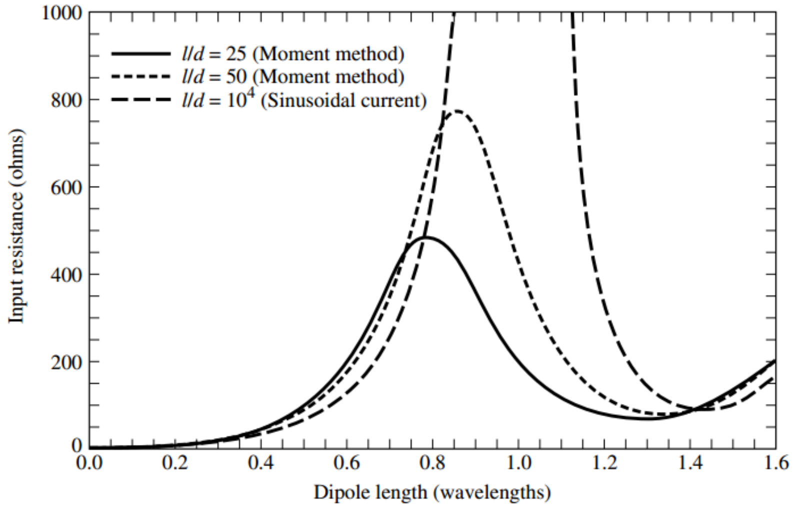
Impedansi

$l = \lambda/2$	$l = 3\lambda/2$
$Z_{in}(l/d = 10^4) = 73 + j42.5$	$Z_{in}(l/d = 10^4) = 105.49 + j45.54$
$Z_{in}(l/d = 50) = 85.8 + j54.9$	$Z_{in}(l/d = 50) = 103.3 + j9.2$
$Z_{in}(l/d = 25) = 88.4 + j27.5$	$Z_{in}(l/d = 25) = 106.8 + j4.9$

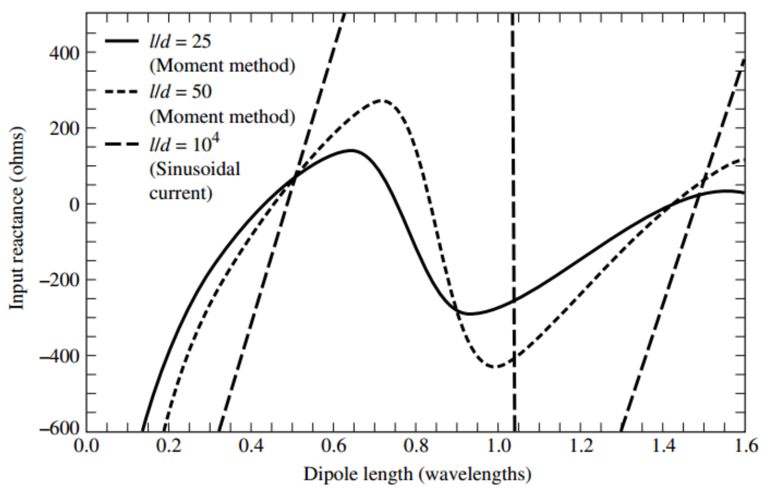
Pola radiasi tidak terlalu dipengaruhi oleh ketebalan dipole

Broadband Dipole

CYLINDRICAL DIPOLE



(a) Input resistance



(b) Input reactance

G. H. Brown and O. M. Woodward Jr., "Experimentally Determined Impedance Character-istics of Cylindrical Antennas," Proc. IRE, Vol. 33, pp. 257 – 262, 1945

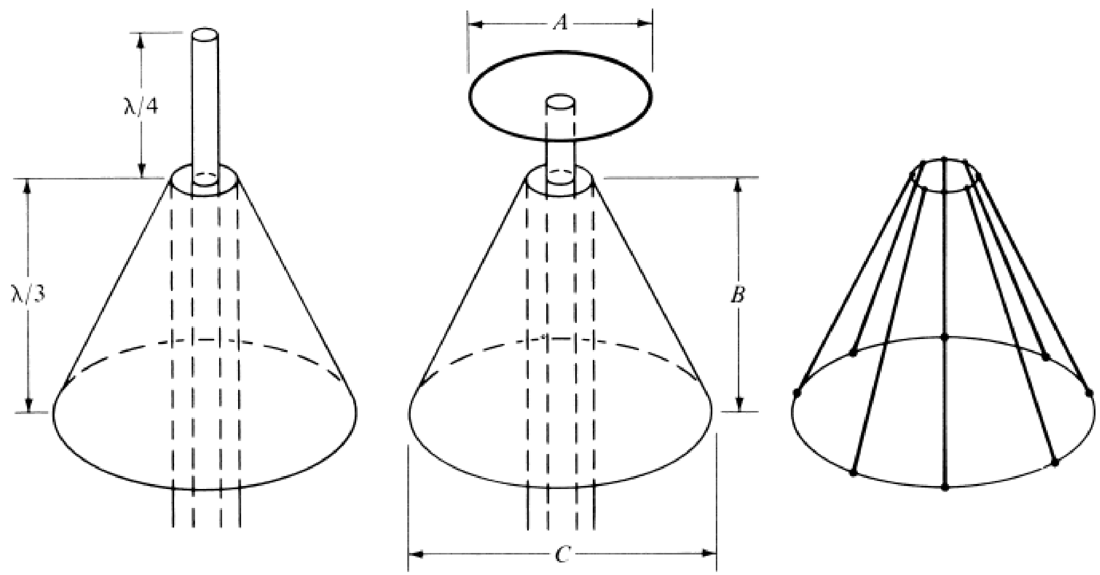
Bandwidth

- l/d ≈ 5000 → BW=3%
- l/d ≈ 260 → BW =30%

Grafik diatas menunjukkan semakin besar diameter dipole bandwidth semakin besar

Broadband Dipole

DISCONE & CONICAL SKIRT MONOPOLE



(a) Conical skirt monopole (b) Discone (c) Wire-simulation

Perancangan Antena Dipole & Monopole

Pendekatan Perancangan

$$0 < G < \pi/4$$

(maximum input resistance of dipole is less than 12.337 ohms)

$$R_{in}\ (\text{dipole}) = 20G^2 \qquad 0 < l < \lambda/4$$

$$R_{in}\ (\text{monopole}) = 10G^2 \qquad 0 < l < \lambda/8$$

$$\pi/4 \le G < \pi/2$$

(maximum input resistance of dipole is less than 76.383 ohms)

$$R_{in}\ (\text{dipole}) = 24.7G^{2.5} \qquad \lambda/4 \le l < \lambda/2$$

$$R_{in}\ (\text{monopole}) = 12.35G^{2.5} \qquad \lambda/8 \le l < \lambda/4$$

$$\pi/2 \le G < 2$$

(maximum input resistance of dipole is less than 200.53 ohms)

$$R_{in}\ (\text{dipole}) = 11.14G^{4.17} \qquad \lambda/2 \le l < 0.6366\lambda$$

$$R_{in}\ (\text{monopole}) = 5.57G^{4.17} \qquad \lambda/4 \le l < 0.3183\lambda$$

$G = kl/2$ for dipole

$G = kl$ for monopole

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

Contoh

Determine the length of the dipole whose input resistance is 50 ohms. Verify the answer.

Solution: Using (4-109a)

$$50 = 24.7G^{2.5}$$

or

$$G = 1.3259 = kl/2$$

Therefore

$$l = 0.422\lambda$$

Questions???

Thank You !