Rev. 2015

Modul#4a

TTG3D3 Antena dan Propagasi

Konsep Dasar Susunan Antena

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Outline

- Filosofi Dasar: Superposisi Medan Listrik
- Susunan 2 Sumber Titik Isotropis
- Prinsip Perkalian Diagram dan Sintesa Pada Susunan Antena Sejenis
- Pencatuan Susunan Antena

Referensi utama:

1) Krauss, J.D., Marhefka, R.J., "Antenna for All Applications", Chapter 5 Arrays of Point Sources Part I, Mc Graw Hill, 2002

Filosofi Dasar

Superposisi Medan Listrik

Filosofi Dasar…

Medan total disuatu titik = superposisi dari medan-medan yang datang dititik tersebut (medan-medan datang dan/atau medan pantul).

$$\vec{E}_t = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + ...$$

Medan total (magnituda dan fasa) suatu susunan antena tergantung dari magnituda dan fasa dari medan-medan yang dihasilkan masing-masing elemen antena.

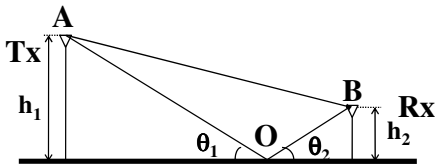
Fasa dari medan-medan yang datang dari masing-masing elemen antena **berbeda** karena adanya perbedaan jarak yang ditempuh masing-masing gelombang.

Jika perbedaan jarak tempuh dua buah gelombang adalah Δd , maka beda fasa antara kedua gelombang tersebut pada titik observasi adalah :

$$\Delta\varphi = \beta.\Delta d = \frac{2\pi}{\lambda}\Delta d$$

Filosofi Dasar…

Contoh..



Di penerima (titik B), medan total adalah penjumlahan / superposisi dari gelombang langsung dan gelombang pantul

Gelombang Langsung (E_{S1})
(Melalui lintasan AB)

$$E_{S1} = E_0 e^{j\varphi_1}$$

Gelombang Pantul (E_{S2})
(Melalui lintasan AOB)

$$E_{S2} = E_0 e^{j\varphi_2}$$

Beda fasa antara kedua gelombang,

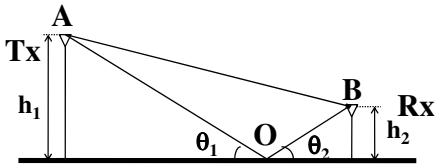
$$\Delta\varphi = \varphi_1 - \varphi_2 = \beta\,\Delta d = \frac{2\pi}{\lambda}(AOB - AB)$$

β = konstanta fasa (rad/m)

Filosofi Dasar…

Persamaan medan totalnya menjadi...

$$\begin{aligned} E_t &= E_{S1} + E_{S2} \\ &= E_0 e^{j\varphi_1} + E_0 e^{j\varphi_2} \\ &= E_0\left(e^{j\varphi_1} + e^{j\varphi_2}\right) \\ &= E_0\left(e^{j\varphi_1} + e^{j(\varphi_1+\Delta\varphi)}\right) \end{aligned}$$



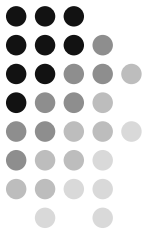
Jika medan E_1 dianggap sebagai referensi (fasanya dianggap = 0), maka akan didapat persamaan :

$$E_t = E_0\left(1 + e^{j\Delta\varphi}\right)$$

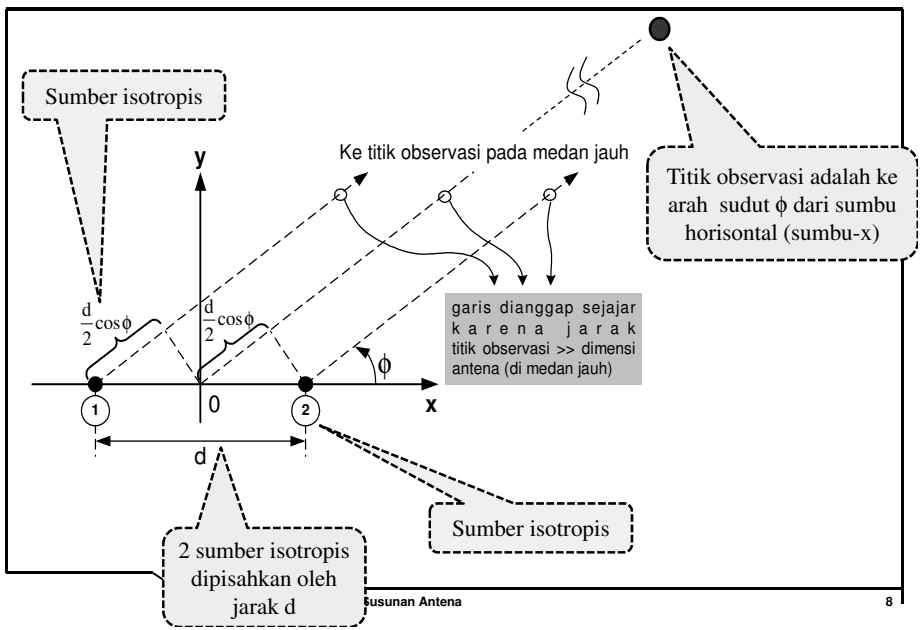
Susunan 2 Sumber Titik Isotropis

Tujuan Membuat Susunan / Array Antena…..

- Mendapatkan diagram arah dengan pola tertentu (***beam forming***)
- Mendapatkan diagram arah dengan pengendalian arah tertentu (***beam steering***)



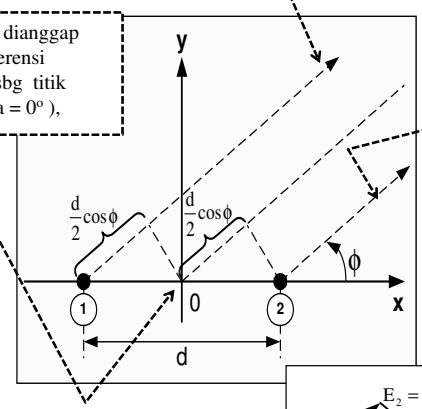
Susunan 2 Sumber Titik Isotropis



Case #1: Amplitudo dan Fasa Sama

Referensi titik 0...

Jika titik **O** dianggap sebagai referensi (dianggap sbg titik dengan fasa = 0°),



Maka, E_1 akan **tertinggal** sebesar :

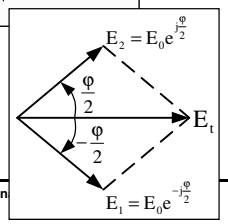
$$\frac{\varphi}{2} = \frac{2\pi}{\lambda}\frac{d}{2}\cos\phi$$

dan medan E_2 akan **mendahului** sebesar :

$$\frac{\varphi}{2} = \frac{2\pi}{\lambda}\frac{d}{2}\cos\phi$$

Sehingga, medan gabungan E_t dapat dituliskan sebagai berikut :

$$E_t = E_0 e^{j\frac{\varphi}{2}} + E_0 e^{-j\frac{\varphi}{2}}$$



Case #1: Amplitudo dan Fasa Sama …(referensi titik O)

$$E_t = E_0 e^{j\frac{\varphi}{2}} + E_0 e^{-j\frac{\varphi}{2}}$$

$$E_t = 2E_0\left(\frac{e^{j\frac{\varphi}{2}} + e^{-j\frac{\varphi}{2}}}{2}\right)$$

$$E_t = 2E_0\cos\frac{\varphi}{2}$$

dengan,

$\varphi = d_r\cos\phi \quad \left| \; d_r = \frac{2\pi}{\lambda}d\right.$

Analisis utk menggambar diagram arah:

$$E_t = 2E_0\cos\frac{\varphi}{2} \qquad \varphi = d_r\cos\phi \quad \left| \; d_r = \frac{2\pi}{\lambda}d\right.$$

Medan **maksimum** , (d = 1/2λ)

$$\cos\frac{\varphi}{2} = 1 \Rightarrow \frac{\pi}{\lambda}d\cos\phi_m = 0$$
$$\Rightarrow \cos\phi_m = 0$$
$$\Rightarrow \phi_m = \frac{\pi}{2}, \frac{3}{2}\pi$$

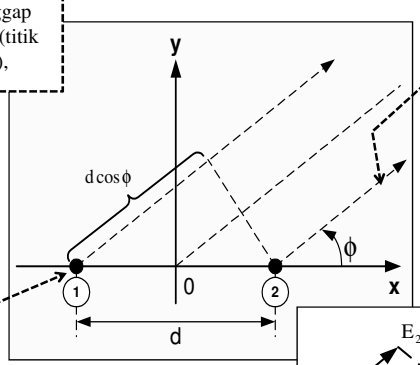
Medan **minimum**, (d = 1/2λ)

$$\cos\frac{\varphi}{2} = 0 \Rightarrow \frac{\pi}{\lambda}\frac{1}{2}\lambda\cos\phi_0 = \frac{\pi}{2}$$
$$\Rightarrow \phi_0 = 0, \pi$$

Case #1: Amplitudo dan Fasa Sama

Referensi titik 1...

Jika titik 1 dianggap sebagai referensi (titik dengan fasa = 0°),

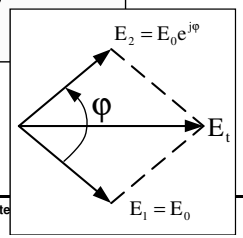


Maka E_2 akan **mendahului** sebesar :

$$\varphi = \frac{2\pi}{\lambda}d\cos\phi$$

Sehingga, medan gabungan E_t dapat dituliskan sebagai berikut :

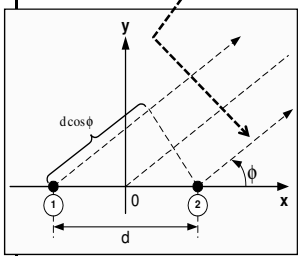
$$E_t = E_0 + E_0 e^{j\varphi}$$



Case #1: Amplitudo dan Fasa Sama … (Ref. titik 1)

E_2 **mendahului** sebesar

$$\varphi = \frac{2\pi}{\lambda}d\cos\phi$$



$$E_t = E_0 + E_0 e^{j\varphi}$$

$$E_t = 2E_0 e^{j\frac{\varphi}{2}}\left(\frac{e^{j\frac{\varphi}{2}} + e^{-j\frac{\varphi}{2}}}{2}\right)$$

Jadi, untuk referensi titik 1

$$E_t = 2E_0\cos\frac{\varphi}{2}e^{j\frac{\varphi}{2}} \qquad \varphi = d_r\cos\phi \quad d_r = \frac{2\pi}{\lambda}d$$

$$E_t = \underbrace{2E_0\cos\frac{\varphi}{2}}_{\text{magnituda}}\underbrace{\angle\frac{\varphi}{2}}_{\text{fasa}}$$

$$E_t = \underbrace{2E_0\cos\left(\frac{\pi}{\lambda}d\cos\phi\right)}_{\text{Pers.Medan}}\underbrace{\angle\frac{\pi}{\lambda}d\cos\phi}_{\text{Pers.Fasa}}$$

Diagram Arah Medan

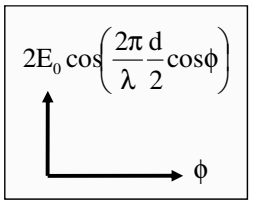
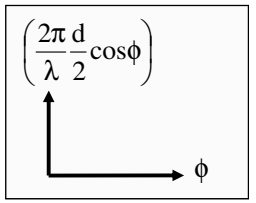


Diagram Fasa



Menggambar Diagram Arah Medan dan Fasa

Referensi titik O...

$$E_t = 2E_0 \cos\frac{\varphi}{2}$$

$$E_t = 2E_0 \cos\left(\frac{1}{2}\frac{2\pi}{\lambda} d\cos\phi\right)$$

$$= 2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi\right) \angle 0$$

Referensi titik 1...

$$E_t = 2E_0 \cos\frac{\varphi}{2} e^{j\frac{\varphi}{2}}$$

$$E_t = \underbrace{2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi\right)}_{\text{Pers.Medan}} \angle \underbrace{\frac{\pi}{\lambda} d\cos\phi}_{\text{Pers.Fasa}}$$

Analisis utk menggambar diagram arah:

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \varphi = d_r \cos\phi \quad \left| \quad d_r = \frac{2\pi}{\lambda} d \right.$$

Medan **maksimum** , (d = 1/2λ)

$$\cos\frac{\varphi}{2} = 1 \Rightarrow \frac{\pi}{\lambda} d\cos\phi_m = 0$$

$$\Rightarrow \cos\phi_m = 0$$

$$\Rightarrow \phi_m = \frac{\pi}{2}, \frac{3}{2}\pi$$

Medan **minimum**, (d = 1/2λ)

$$\cos\frac{\varphi}{2} = 0 \Rightarrow \frac{\pi}{\lambda}\frac{1}{2}\lambda\cos\phi_0 = \frac{\pi}{2}$$

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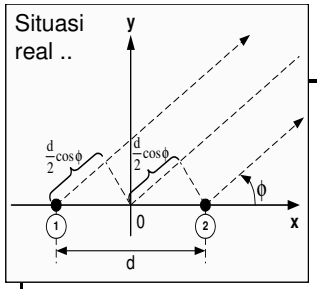
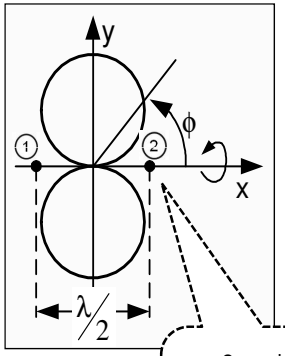
Menggambar Diagram Arah Medan



Bentuk radiasi "**Donat**" (*broadside*)



Analisis utk menggambar diagram arah:

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \varphi = d_r \cos\phi \quad \left| \quad d_r = \frac{2\pi}{\lambda} d \right.$$

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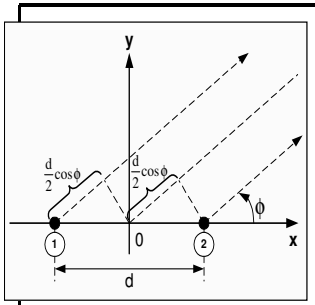
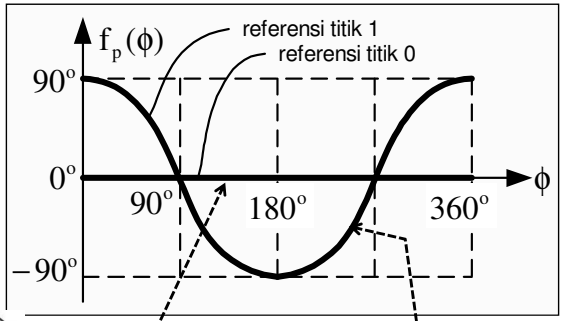
$$\cos\frac{\varphi}{2} = 0 \Rightarrow \frac{\pi}{\lambda}\frac{1}{2}\lambda\cos\phi_0 = \frac{\pi}{2}$$

$$\Rightarrow \phi_0 = 0, \pi$$

2 sumber titik diletakkan segaris horisontal → maka bentuk pola radiasi: **Donat Berdiri**

Menggambar Diagram Fasa





Referensi titik O...

$$E_t = 2E_0 \cos\frac{\varphi}{2}$$

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$$= 2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi\right) \angle 0$$

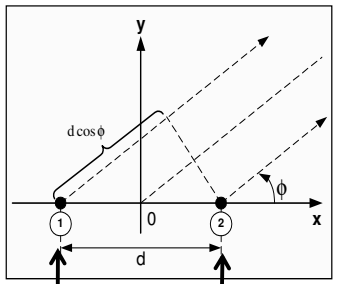
Referensi titik 1...

$$E_t = 2E_0 \cos\frac{\varphi}{2} e^{j\frac{\varphi}{2}}$$

$$E_t = \underbrace{2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi\right)}_{\text{Pers.Medan}} \angle \underbrace{\frac{\pi}{\lambda} d\cos\phi}_{\text{Pers.Fasa}}$$

Pengaruh Perbedaan Fasa Catuan Arus

Referensi titik 0...



Beda fasa arus = 0° (Ref. titik 0)

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \left| \quad \varphi = \frac{2\pi}{\lambda} d\cos\phi \right.$$

$$E_t = \underbrace{2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi\right)}_{\text{Pers.Medan}}$$

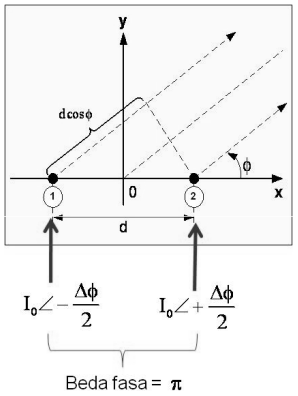
Jika beda fasa arus = Δ ϕ (Ref. titik 0)

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \left| \quad \boxed{\varphi = \frac{2\pi}{\lambda} d\cos\phi + \Delta\phi} \right.$$

$$E_t = \underbrace{2E_0 \cos\left(\frac{\pi}{\lambda} d\cos\phi + \frac{\Delta\phi}{2}\right)}_{\text{Pers.Medan}}$$

Case #2: Amplitudo Sama, Beda Fasa = 180°

Referensi titik 0...



$$E_t = 2E_0 \cos\frac{\varphi}{2} \qquad \varphi = \frac{2\pi}{\lambda} d\cos\phi + \pi$$

$$E_t = 2E_0 \cos\left[\frac{\pi}{\lambda} d\cos\phi + \frac{\pi}{2}\right]$$

Nilai maksimum, d = ½λ

$$\frac{\pi}{2}\cos\phi_m = \pm(2k+1)\frac{\pi}{2}$$

$$\boxed{\phi_m = 0, \pi}$$

Nilai minimum, d = ½λ

$$\frac{\pi}{2}\cos\phi_0 = \pm k\pi$$

$$\boxed{\phi_0 = \frac{\pi}{2}, \frac{3}{2}\pi}$$

Nilai ½ daya, d = ½λ

$$\frac{\pi}{2}\cos\phi_{½} = \frac{1}{2}\sqrt{2}$$

$$\frac{\pi}{2}\cos\phi_{½} = \pm(2k+1)\frac{\pi}{4}$$

$$\boxed{\phi_{½} = 60^o}$$

$$\text{HPBW} = 2\phi_{½} = 120^o$$

Diagram Arah: Amplitudo Sama, Beda Fasa = 180°

Nilai maksimum, d = ½λ

$$\frac{\pi}{\lambda}\cos\phi_m = \pm(2k+1)\frac{\pi}{2}$$

$$\boxed{\phi_m = 0, \pi}$$

Nilai minimum, d = ½λ

$$\frac{\pi}{\lambda}\cos\phi_0 = \pm k\pi$$

$$\boxed{\phi_0 = \frac{\pi}{2}, \frac{3}{2}\pi}$$

Nilai ½ daya, d = ½λ

$$\frac{\pi}{2}\cos\phi_{½} = \frac{1}{2}\sqrt{2}$$

$$\frac{\pi}{2}\cos\phi_{½} = \pm(2k+1)\frac{\pi}{4}$$

$$\boxed{\phi_{½} = 60^o}$$

$$\text{HPBW} = 2\phi_{½} = 120^o$$

Persamaan medan total:

$$E_t = 2E_0 \cos\left[\frac{\pi}{\lambda} d\cos\phi + \frac{\pi}{2}\right]$$

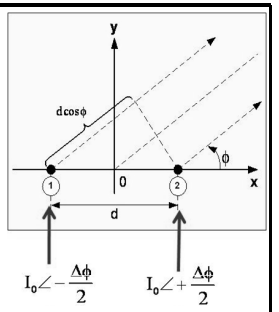
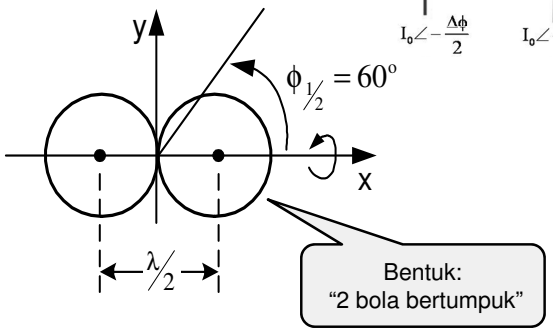
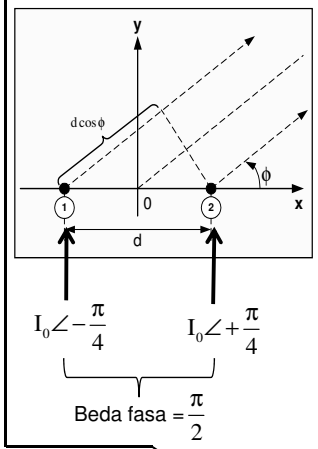


Diagram arah medan:



Case #3: Amplitudo Sama, Beda Fasa = 90°

Referensi titik 0...



$$E_t = 2E_0 \cos\frac{\varphi}{2} \qquad \varphi = \frac{2\pi}{\lambda} d\cos\phi + \frac{\pi}{2}$$

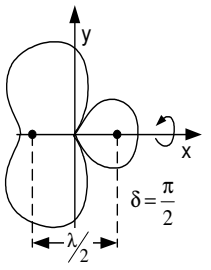
$$E_t = 2E_0 \cos\left[\frac{\pi}{\lambda} d\cos\phi + \frac{\pi}{4}\right]$$

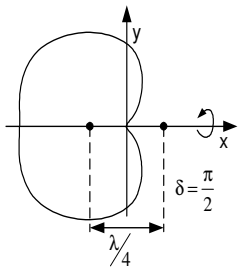
Cari nilai medan **maks** dan **min**, terutama untuk sudut-sudut istimewa.

Buat tabel sbb :

ϕ	$E_t(\phi)$
0°	
10°	
dst	

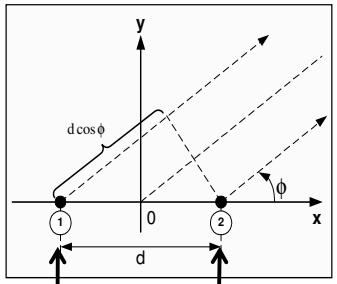
setelah itu…plot !!

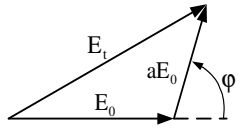




General Case: Amplitudo Beda, Beda Fasa = δ

Referensi titik 1





Misal :

$$|E_1| = E_0 \quad \textbf{dan} \quad |E_2| = aE_0$$

Beda fasa **sembarang** !!

Bentuk Umum :

$$E_t = E_0\sqrt{(1+a\cos\varphi)^2 + a^2\sin^2\varphi}\,\angle\tan^{-1}\left(\frac{a\sin\varphi}{1+a\cos\varphi}\right)$$

$$\varphi = \frac{2\pi}{\lambda} d\cos\phi + \delta$$

Prinsip Perkalian Diagram dan Sintesa Pada Susunan Antena Sejenis

Prinsip Perkalian Diagram

- Misalkan **antena A**, memiliki fungsi diagram arah sbb:

$$E_e = f(\theta,\phi).e^{jf_p(\theta,\phi)}$$

- **Susunan n-**antena isotropis memiliki diagram arah :

$$E_{ti} = E_0\, F(\theta,\varphi).e^{jF_p(\theta,\varphi)}$$

- **"Prinsip Perkalian Diagram " :**

→ **Susunan n-antena A (sejenis)**, akan memiliki diagram arah, sbb :

$$E_{te} = \underbrace{E_0\, f(\theta,\varphi)\, F(\theta,\varphi)}_{\text{magnitude medan}} \angle \underbrace{f_p(\theta,\varphi) + F_p(\theta,\varphi)}_{\text{fasa}}$$

EXAMPLE 5–3.1

Assume two identical point sources separated by a distance d, each source having the field pattern given by (1) as might be obtained by two short dipoles arranged as in Fig. 5–7. Let $d = \lambda/2$ and the phase angle $\delta = 0$. Then the total field pattern is

$$E = \sin\phi \cos\left(\frac{\pi}{2}\cos\phi\right) \quad (5)$$

This pattern is illustrated by Fig. 5–8*c* as the product of the individual source pattern ($\sin\phi$) shown at (*a*) and the array pattern {$\cos[(\pi/2)\cos\phi]$} as shown at (*b*). The pattern is sharper than it was in Case 1 (Sec. 5–2) for the isotropic sources. In this instance, the maximum field of the individual source is in the direction $\phi = 90°$, which coincides with the direction of the maximum field for the array of two isotropic sources.

JD Krauss, Marhefka, RJ, "***Antennas For All Applications***", McGraw-Hill, 2002 page-100

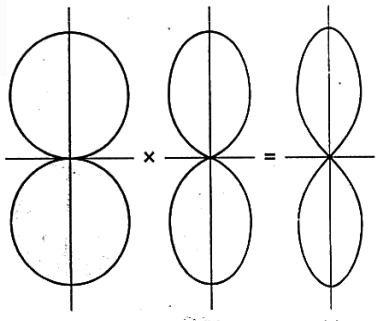


Figure 5–8
Example of pattern multiplication. Two nonisotropic but identical point sources of the same amplitude and phase, spaced $\lambda/2$ apart and arranged as in Fig. 5–7, produce the pattern shown at (*c*). The individual source has the pattern shown at (*a*), which, when multiplied by the pattern of an array of two isotropic point sources (of the same amplitude and phase) as shown at (*b*), yields the total array pattern of (*c*).

Prinsip Perkalian Diagram

JD Krauss, Marhefka, RJ, "***Antennas For All Applications***", McGraw-Hill, 2002 page-101

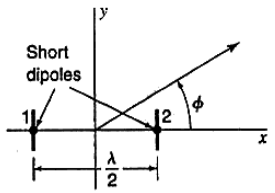


Figure 5–9
Array of two nonisotropic sources with respect to the coordinate system.

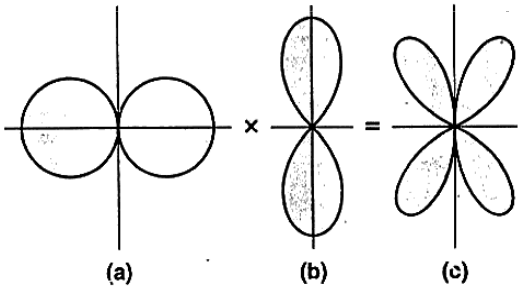


Figure 5–10
Example of pattern multiplication. Total array pattern (*c*) as the product of pattern (*a*) of individual nonisotropic source and pattern (*b*) of array of two isotropic sources. The pattern (*b*) for the array of two isotropic sources is identical with that of Fig. 5–8*b*, but the individual source pattern (*a*) is rotated through 90° with respect to the one in Fig. 5–8*a*.

Sintesa Diagram

- **Definisi / tujuan sintesa** *Proses untuk mencari sumber atau susunan yang memberikan diagram arah sesuai keinginan designer*
- **Problem sintesa** *Sintesa diagram tidak selalu sederhana dan mungkin menghasilkan susunan yang kurang realiable. Salah satu sintesa yang sederhana adalah dengan menggunakan* ***Prinsip Perkalian Diagram***

- **Contoh persoalan sintesa**
  Carilah susunan antena yang mempunyai diagram arah dengan radiasi maksimum ke arah utara ($\phi = 0$) dan radiasi minimum ke arah barat, timur, tenggara, dan barat daya

Sintesa Diagram

- **Pada susunan primer**

Bentuk umum :

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \Big| \quad \varphi = \frac{2\pi}{\lambda} d\cos\phi + \delta$$

→ Misalkan kita tentukan **d = 0,3 λ**

$$E_1 = \cos\frac{\varphi}{2} \text{ dengan } \varphi = \frac{2\pi}{\lambda}(0{,}3\lambda)\cos\phi + \delta = 0{,}6\pi\cos\phi + \delta$$

$E_1 = 0$ pada $\phi = 135^o \Rightarrow \varphi = (2k+1)\pi$, $k = 0,1,2,..dst$

Maka :

$$-0{,}6\pi\frac{1}{\sqrt{2}} + \delta = (2k+1)\pi$$

$$\Rightarrow \delta = (2k+1)\pi + 0{,}425\pi \quad \Big| \quad k = 0 \Rightarrow \delta = -104^o$$

Sintesa Diagram

- **Pada susunan sekunder**

Bentuk umum :

$$E_t = 2E_0 \cos\frac{\varphi}{2} \quad \Big| \quad \varphi = \frac{2\pi}{\lambda} d\cos\phi + \delta$$

→ Misalkan kita tentukan **d = 0,6 λ**

$$E_2 = \cos\frac{\varphi}{2} \text{ dengan } \varphi = \frac{2\pi}{\lambda}(0{,}6\lambda)\cos\phi + \delta = 1{,}2\pi\cos\phi + \delta$$

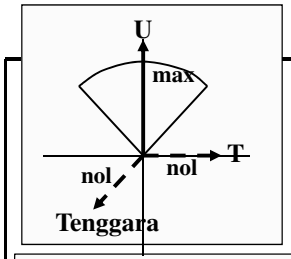
$E_2 = 0$ pada $\phi = 270^o \Rightarrow \delta = 180^o$

- **Jadi, medan total hasil perkalian :**

$$E_t = E_1 \times E_2 = \cos\frac{(0{,}6\pi\cos\phi - 104^o)}{2} \times \cos\frac{(1{,}2\pi\cos\phi + 180^o)}{2}$$

$$= \cos(54^o\cos\phi - 52^o)\cos(108^o\cos\phi + 90^o)$$

Sintesa Diagram



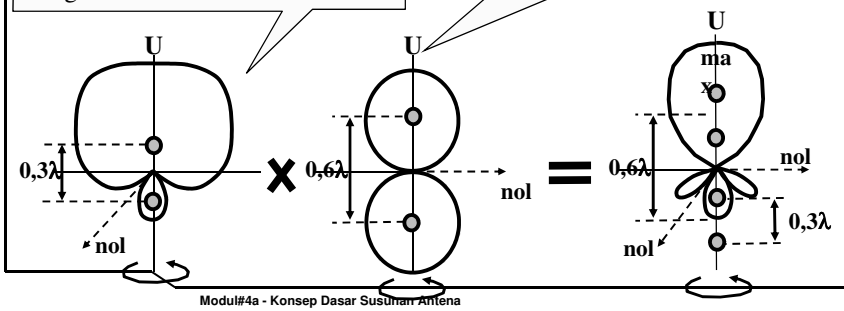
Ilustrasi ….

Syarat

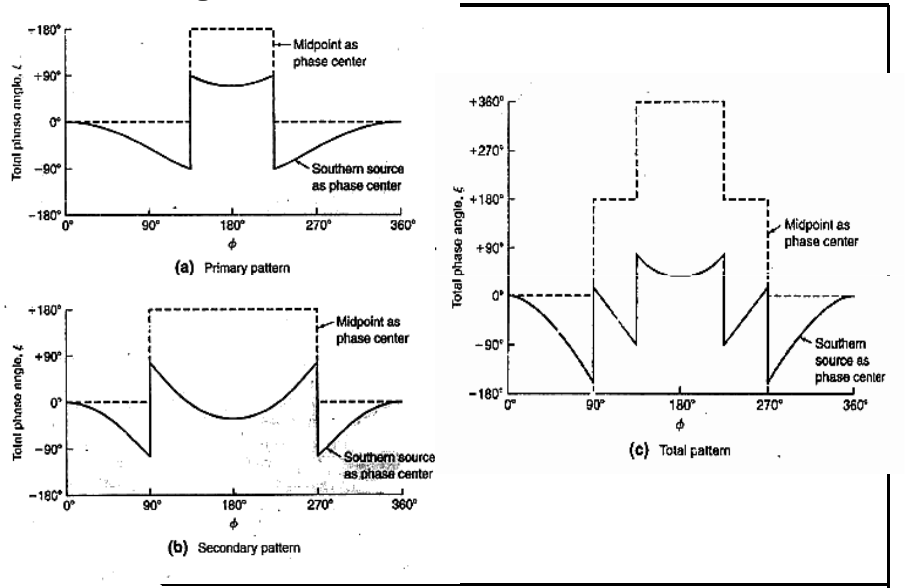
Maximum ke arah utara, null ke arah timur (90°) dan tenggara (135°)

Null ke arah tenggara (135°), bisa diimplementasikan dengan susunan 2 antena isotropik berjarak **0,3λ** dengan beda fasa **-104°**.

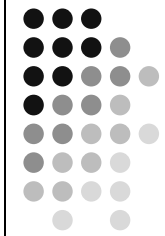
Null ke arah timur (90°), bisa diimplementasikan dengan susunan 2 antena isotropik berjarak **0,6λ** dengan beda fasa **-180°.**



Sintesa Diagram



Pencatuan Susunan Antena



End Of Modul#4a