UNIT : 3

Parasitic Arrays :

The element supplied power directly from the source (ie transmitter) usally through the transmission line is called as driven element.

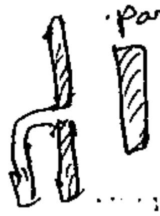
parasitic element derives power by radiation from nearby driven element.

Driven element

Reflector

parasitic element lengthened

parasitic element



parasitic element shortend

point source :

It is Volume less radiator.

In other words a hypothetical antenna (or) Isotropic or omni-directional or non directional antenna which occupies zero volume.

Multiplication pattern:

$$E = \{E_i(\theta,\phi) \times E_a(\theta,\phi)\} \times \{E_{pi}(\theta,\phi) + E_{pa}(\theta,\phi)\}$$

Multiplication of field pattern — Addition of phase pattern.

$E_i(\theta,\phi)$ → ~~?~~ Field pattern of individual source

$E_a(\theta,\phi)$ → Field pattern of point array of isotropic sources

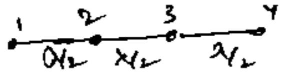
$E_{pi}(\theta,\phi)$ = ~~phase~~ phase pattern of individual source

$E_{pa}(\theta,\phi)$ = phase pattern of Array of isotropic point sources.

→ Definition

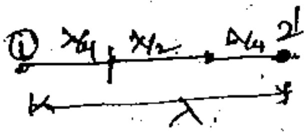
Multiplication of pattern (or) Simply pattern multiplication, in general can be stated as follows.

The total field pattern of an array of non-isotropic sources but similar sources is the multiplication of the individual source patterns & the pattern of array of isotropic point sources and having the relative amplitude & phase. where as the total phase pattern is the addition of the phase patterns of the individual sources & that of the array of isotropic point sources

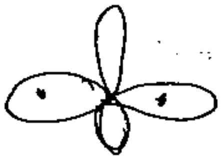


4 isotropic elements spaced λ/2

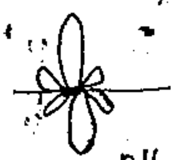
Now the elements 1 & 2 are considered as one unit & is considered to be placed in the midway of the elements. & also the elements, 3 & 4 are considered as another unit. shown in figure



Individual patter



Group pattern due to array of two



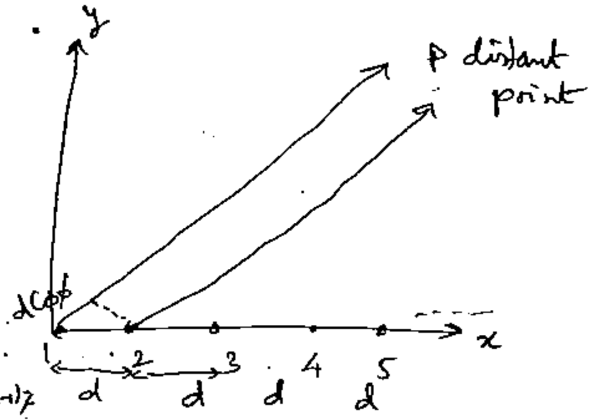
Pattern of 4 isotropic elements.

Linear Array with n isotropic point sources of equal amplitude & spacing

An array is said to be linear, if the individual elements of the array are spaced equally along a line and uniform, if the same are fed with currents of equal amplitude and having uniform progressive phase shift along the line.

We shall now calculate the pattern of a linear array of n isotropic point sources in which point sources are spaced equally (by d) and are fed with in phase currents of equal amplitude (say E_0) as shown in fig.

The total far field pattern at a distant point P is obtained by adding vectorially all the fields of individual sources as



$$E_t = E_0 e^{j0\psi} + E_0 e^{j\psi} + E_0 e^{2j\psi} + \cdots + E_0 e^{j(n-1)\psi}$$

$$E_t = E_0 [1 + e^{j\psi} + e^{2j\psi} + \cdots + e^{j(n-1)\psi}] \quad -(1)$$

where $\psi = \beta d \cos\phi + \alpha$

ψ is total phase difference of the fields at point P from the adjacent sources.

α = Phase difference in adjacent point sources

Multiply eq (1) by $e^{j\psi}$

$$E_t e^{j\psi} = E_0 [e^{j\psi} + e^{2j\psi} + e^{3j\psi} + \cdots + e^{jn\psi}] \quad -(2)$$

Subtracting eq (2) from (1).

$$E_t (1 - e^{j\psi}) = E_0 (1 - e^{jn\psi})$$

$$E_t = E_0 \frac{(1 - e^{jn\psi})}{(1 - e^{j\psi})}$$

$$E_t = E_0 \frac{e^{jn\psi/2} [e^{jn\psi/2} - e^{-jn\psi/2}]}{e^{j\psi/2} [e^{j\psi/2} - e^{-j\psi/2}]} = E_0 \, e^{j(n-1)\psi/2} \frac{\sin n\psi/2}{\sin \psi/2}$$

$$\left\{ \frac{\sin(n\psi/2)}{} \right\} e^{j\phi} \quad \text{where } \phi = \frac{(n-1)\psi}{2}$$

$$E_t = E_0 \left\{ \frac{\sin n\psi/2}{\sin \psi/2} \right\} \cdot \cos(\omega t + \phi) \text{ any}$$

$$E_t = E_0 \left\{ \frac{\sin n\psi/2}{\sin \psi/2} \right\} \cdot \angle\phi.$$

As $\psi \to 0$

$$\lim_{\psi \to 0} E_t = E_0 \lim_{\psi \to 0} \frac{\frac{d}{d\psi} \sin n\psi/2}{\frac{\partial}{\partial\psi} \sin \psi/2}$$

$$= E_0 \frac{\cos n\psi/2 \cdot n/2}{\cos \psi/2 \cdot 1/2}$$

$$\boxed{E_{t\,max} = n \cdot E_0.}$$

Thus the max value of E_t is n times the field from the source. If E_0 is assumed to be unity, for a normalization then

$$\boxed{E_{t\,max} = n}$$

Therefore, the field from the array is maximum in any direction θ, when $\psi = 0$.

The Normalized field pattern obtained from

$$E_{normal} = \frac{E_t}{E_{t\,max}} = \frac{E_0}{E_0 \cdot n} \cdot \frac{\sin(n\psi/2)}{\sin \psi/2}$$

$$\boxed{E_{norm} = \frac{\sin(n\psi/2)}{n \cdot \sin \psi/2}}$$

Array of n Isotropic Sources of equal amplitude and Spacing (Broadside Case)

An array is said to be broad side array, if phase angle is such that it makes maximum radiation perpendicular to the line of array ie 90° (or) 270°.

In broad side array sources are in phase ie $\alpha = 0$ & $\psi = 0$ for max. must be satisfied.

$$\psi = \beta d\cos\theta + \alpha$$
$$= \beta d\cos\theta + 0 \Rightarrow \beta d\cos\theta.$$

Max. radiation $\psi = 0 \Rightarrow \beta d\cos\theta = 0$
$$\Rightarrow \cos\theta = 0$$
$$\theta = 90^\circ \text{ (or) } 270^\circ$$

the principle maxima occurs in these directions.

The other minor lobes maxima occurs b/w First nulls & high order nulls.

Direction of pattern maxima

Consider $E_t = E_0 \dfrac{\sin(n\psi/2)}{\sin\psi/2}$

This is max. when Nr. is maximum ie $\sin n\psi/2$ is max.

$$\therefore \sin(n\psi/2) = 1.$$

$$n\psi/2 = \pm(2N+1)\pi/2 \qquad N = 1,2,3,4\ldots$$

N=0 Corresponds to major lobe maxima

$$\psi/2 = \pm(2N+1)\cdot\frac{\pi}{2n}$$
$$\psi = \pm(2N+1)\pi/n$$
$$\beta d\cos\theta + \alpha = \pm(2N+1)\pi/n$$
$$\beta d\cos\theta = \pm(2N+1)\frac{\pi}{n} - \alpha$$
$$\theta = \cos^{-1}\left\{\frac{1}{\beta d}\left[\pm(2N+1)\frac{\pi}{n} - \alpha\right]\right\}$$

where θ is minor lobe maxima

For Broad side

$$\therefore \theta = \cos^{-1}\left[\frac{1}{\beta d}\left(\pm(2N+1)\frac{\pi}{n}\right)\right]$$

$$\theta = \cos^{-1}\left[\pm\frac{(2N+1)\lambda}{2nd}\right]$$

For example

Let $n=4$, $d=\lambda/2$, $\alpha=0$.

$$\theta = \cos^{-1}\left[\pm\frac{(2N+1)\lambda}{2\times 4\times \lambda/2}\right] = \cos^{-1}\left[\pm\frac{2N+1}{4}\right]$$

If $N=1$

$$\theta = \cos^{-1}(\pm 3/4)$$

$$= \pm 41.4^\circ \text{ (or) } \pm 138.6^\circ$$

Directions of the pattern minima

$$E_t = E_0 \cdot \frac{\sin n\psi/2}{\sin \psi/2} = 0.$$

$$\sin n\psi/2 = 0$$

$$\therefore n\psi/2 = \pm N\pi$$

$$\psi = \pm\frac{2N\pi}{n}$$

For Broad side

$$\beta d \cos\theta = \pm\frac{2N\pi}{n}$$

$$\cos\theta = \frac{1}{\beta d}\left[\pm\frac{2N\pi}{n}\right]$$

$$\theta = \cos^{-1}\left[\frac{1}{\beta d}\left(\pm\frac{2N\pi}{n}\right)\right]$$

$$\theta = \cos^{-1}\left(\frac{N\lambda}{nd}\right)$$

for example $n=4$, $d=\lambda/2$.

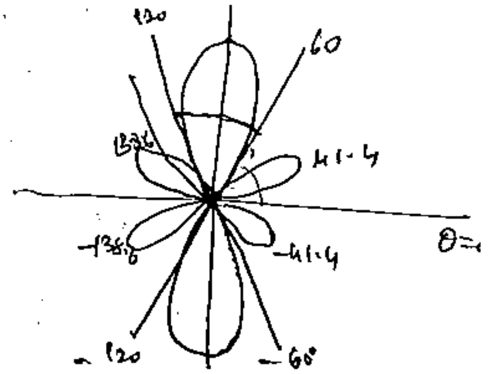
$$\theta = \cos^{-1}\left(\frac{N\lambda}{4\,\lambda/2}\right) = \cos^{-1}(N/2).$$

If $N=1$, $\theta = \cos^{-1}(\pm 1/2) = 60^\circ$ (or) 120°

$N=2$, $\theta = \cos^{-1}(1) = 0^\circ$ (or) 180°

It is the angle between first Nulls.

$\therefore$ Beam width of major lobe $= 2\times$ Angle b/w the first null & max of major lobe



$$BWFN = 2\times\gamma$$

But $\gamma = 90-\theta$.

we know $\theta = \cos^{-1}\left[\frac{\pm N\lambda}{nd}\right]$

$$90-\gamma = \cos^{-1}\left[\frac{\pm N\lambda}{nd}\right]$$

$$\cos(90-\gamma) = \frac{\pm N\lambda}{nd} \Rightarrow \sin\gamma = \frac{\pm N\lambda}{nd}$$

If γ is very small, $\sin\gamma = \gamma$

$$\therefore \boxed{\gamma = \frac{\pm N\lambda}{nd}}$$

When $N=1$, $\gamma = \lambda/nd$ $\quad \therefore BWFN = 2\gamma = \frac{2\lambda}{nd}$

$$\therefore BWFN = \frac{2\lambda}{L} \qquad \because nd = L$$

$L =$ Length of the array (if n is large)

$$\therefore BWFN = \frac{2}{L/\lambda} \text{ radian} = \frac{2\times 57.3}{L/\lambda} \text{ degree}$$

$$\boxed{BWFN = \frac{114.6^\circ}{L/\lambda}}$$

$$\boxed{HPBW = \frac{BWFN}{2} = \frac{1}{L/\lambda} \text{ radian} = \frac{57.3}{L/\lambda} \text{ degree.}}$$

$\Rightarrow$ Array of n Sources of Equal Amplitude and Spacing (End Fire Case)

For an array to be end fire, the phase angles is such that the max. radiation in the line of array ie $\theta = 0°$ (or) $180°$.

Thus for an array to be end fire $\psi = 0$ & $\theta = 0°$ (or) $180°$.

$$\psi = \beta d\cos\theta + \alpha$$

$$0 = \beta d\cos 0 + \alpha \Rightarrow \boxed{\alpha = -\beta d}.$$

Direction of pattern Maxima:

$$E = E_0 \frac{\sin n\psi/2}{\sin \psi/2} \quad \text{--- (1)}$$

The other pattern max. can be obtained from eq (1), when $\sin n\psi/2 = 1$

GATE - 13

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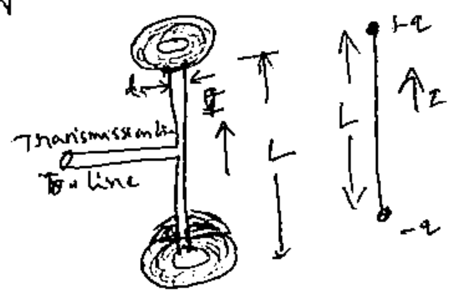
Short Electric Dipole:

A short linear conductor is called a short dipole. Short Dipole has finite length though it may be very short. If the dipole is vanishingly short, it is an infinitesimal dipole.

Let us consider a short dipole, the length is very short compared to λ. ($L << \lambda$). plates at the end of the dipole provides capacitive loading. The short length & presence of these plates provides uniform current I along the entire length 'L' of the dipole.

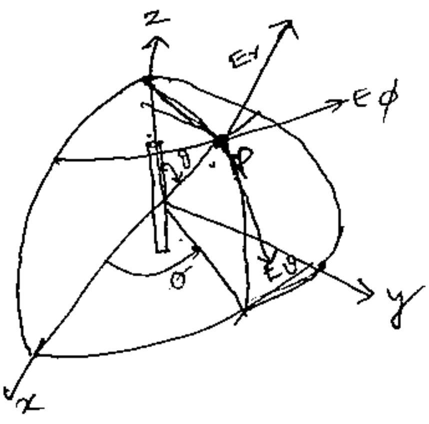
The current & charge related by $\frac{dq}{dt} = I$



other terms sometimes used as elemental dipole, elementary doublet, Hertzian dipole.

Fields of short Dipole:

Let the dipole of length 'L' is placed coincident with the Z axis & with its center at the origin. It is assumed that the medium surrounding the dipole is air or vacuum.



Let the instantaneous current 'I' in the elements be a sinusoidal function of time as

$I = I_m \sin \omega t$

I_m = maximum (or) peak current

I = Instantaneous current.

$\omega = 2\pi f$ (angular frequency)

If the finite time of propagation is taken to account then the instantaneous current is

$$[I] = I_m \sin\omega\left[t - r/v\right]$$

where r = distance travelled, v = velocity of propagation

The point P at a distance 'r' from current element at which different components of EM wave is to be determined.

The vector magnetic potentials due to current element is determined by.

$$A = \frac{\mu}{4\pi}\int_V \frac{J(t-r/v)}{r}\,dv$$

Since the alternating current element is aligned along the the direction of z-axis, the component of vector magnetic potential along x & y axes will be zero ie $A_x = A_y = 0$.

$$\therefore \bar{A} = A_z \bar{a}_z$$

$$A_z = \frac{\mu}{4\pi r}\int_V J\left(t-\frac{r}{v}\right) dv.$$

$\because$ current element is excited by the current $I = I_m \cos\omega t$. So

$\int_V J\,dv$ is replaced by $I\,dl$.

$$A_z = \frac{\mu I\,dl}{4\pi r} = \frac{\mu\, I\,dl \cos\omega(t - r/v)}{4\pi r}.$$

$\because$ Antennas exhibit spherical system symmetry, we need to know the component of vector magnetic potential along $r, \theta, \& \phi$ direction.

Due to sperical symmetry in x y plane, the components of A are

$$\partial/\partial\phi = 0, \quad A_\phi = 0.$$

$$A_r = A_z \cos\theta$$
$$A_\theta = -A_z \sin\theta \qquad — (1)$$

Curl of a vector magnetic potential along the spherical coordinates is given by

$$\nabla \times A = \frac{1}{r\sin\theta}\left[\frac{d}{d\theta}[A_\phi \sin\theta] - \frac{\partial}{\partial\phi}(A_\theta)\right]\hat{a}_r + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\phi}(A_r) - \frac{\partial}{\partial r}(rA_\phi)\right]\hat{a}_\theta$$
$$+ \frac{1}{r}\left[\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial}{\partial\theta}(A_r)\right]\hat{a}_\phi \qquad — (2)$$

$\because$ Since $A_\phi = 0$, $\frac{\partial}{\partial\phi} = 0$, eq (2) becomes

$$\nabla \times A = \frac{1}{r}\left[\frac{\partial}{\partial r}(rA_\theta) - \frac{\partial}{\partial\theta}(A_r)\right]\hat{a}_\phi$$

Using (#).

$$\nabla \times A = \frac{1}{r}\left[\frac{\partial}{\partial r}(-r A_z \sin\theta) - \frac{\partial}{\partial\theta}(A_z \cos\theta)\right]\hat{a}_\phi$$

But $A_z = \frac{\mu}{4\pi r} I dl \cos w(t - r/v)$.

$$\nabla \times A = \frac{1}{r}\left[\frac{\partial}{\partial r}\left[-r\sin\theta \frac{\mu}{4\pi r} I dl \cos w(t - r/v)\right] - \frac{\partial}{\partial\theta}\frac{[\cos\theta\, \mu I dl \cos w(t-r/v)]}{4\pi r}\right]$$

$$\nabla \times A = \frac{\mu I dl}{4\pi r}\left[\sin\theta \frac{\partial}{\partial r}(\cos w(t - r/v))\right] - \frac{\cos w(t-r/v)}{r}\,\partial/\partial\theta(\cos\theta)\Big]$$

$$= \frac{\mu I dl}{4\pi r}\left[\sin\theta \cdot -\sin w(t - r/v)\left(w \cdot -\frac{1}{v}\right)\right] - \frac{\cos w(t-r/v)}{r}(-\sin\theta)\,\hat{a}_\phi$$

$$= \frac{\mu I dl}{4\pi r}\left[-w\sin\theta \sin w(t-r/v) + \frac{\cos w(t-r/v)\cdot \sin\theta}{r}\right]\hat{a}_\phi$$

$$\boxed{\nabla \times A = \frac{\mu I dl \sin\theta}{4\pi}\left[-\frac{w \sin w(t-r/v)}{rv} + \frac{\cos w(t-r/v)}{r^2}\right]\hat{a}_\phi.}$$

But $\nabla \times A = B$ & $B = \mu H$

$H = \frac{1}{\mu}(\nabla \times A)$.

$$\boxed{H_\phi = \frac{I dl \sin\theta}{4\pi}\left[-w\frac{\sin w(t-r/v)}{rv} + \frac{\cos w(t-r/v)}{r^2}\right]}$$

Curl of magnetic field in Spherical Coordinate system

$$\nabla \times H = \frac{1}{r\sin\theta}\left[\frac{\partial}{\partial\theta}(H_\phi \sin\theta) - \frac{\partial}{\partial\phi}(H_\theta)\right]\hat{a}_r + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\phi}(H_r) - \frac{\partial}{\partial r}(r H_\phi)\right]\hat{a}_\theta + \frac{1}{r}\left[\frac{\partial}{\partial r}(r H_\theta) - \frac{\partial}{\partial\theta}(H_r)\right]\hat{a}_\phi.$$

The component of curl of magnetic field intensity along r coordinate is

$$(\nabla \times H)_r = \frac{1}{r\sin\theta}\left[\frac{\partial}{\partial\theta}(H_\phi \sin\theta) - \frac{\partial}{\partial\phi}(H_\theta)\right]$$

$\because A_\phi = 0$, $\frac{\partial}{\partial\phi} = 0$.

$\partial\,(H_\phi \sin\theta)$.

$$(\nabla \times H)_r = \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\sin\theta\left[\frac{I\,dl\sin\theta}{4\pi}\left(\frac{-\omega\sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right)\right]$$

$$= \frac{1}{r\sin\theta}\left[\frac{I\,dl\sin\theta}{4\pi}\left[-\frac{\omega\sin(\omega(t-r/v))}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right]\frac{\partial}{\partial\theta}\sin^2\theta\right].$$

$$\therefore (\nabla\times H)_r = \frac{I\,dl}{4\pi r\sin\theta}\left[-\omega\frac{\sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right]\cdot 2\sin\theta\cos\theta.$$

$$(\nabla\times H)_\theta = \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\phi}(H_r) - \frac{\partial}{\partial r}(r H_\phi)\right] = \frac{1}{r}\left[\frac{-\partial}{\partial r}(r H_\phi)\right]$$

$$\frac{1}{r}\cdot\left[\frac{-\partial}{\partial r}\left[r\,\frac{I\,dl\sin\theta}{4\pi}\left(-\omega\frac{\sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right)\right]\right],$$

$$= \frac{I\,dl\sin\theta}{4\pi}\left\{\left[\frac{-\omega\cos\omega(t-r/v)\;(-\omega/v)}{v}\right] - \left[\frac{r(-\sin\omega(t-r/v)\left[\frac{-\omega}{v}\right]) - \cos\omega(t-r/v)(1)}{r^2}\right]\right.$$

$$(\nabla\times H)_\theta = \frac{I\,dl\sin\theta}{4\pi r}\left[\frac{\omega^2\cos\omega(t-r/v)}{v} - \frac{\omega\sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right]$$

$$(\nabla\times H)_\phi = 0$$

By Definition $\nabla\times H = J + \epsilon\frac{\partial E}{\partial t}$

For charge free region, $J=0$

$$\nabla\times H = \epsilon\frac{\partial E}{\partial t}$$

$$\frac{1}{\epsilon}(\nabla\times H)\,\partial t = \partial E$$

$$E = \frac{1}{\epsilon}\int \nabla\times H\,\partial t.$$

$$\therefore E_r = \frac{1}{\epsilon}\int\left[\frac{2I\,dl\cos\theta}{4\pi r}\left(\frac{-\omega\sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right)\right]dt$$

$$= \frac{1}{\epsilon}\frac{2I\,dl\cos\theta}{4\pi r}\left[-\frac{\omega}{rv}\int\sin\omega(t-r/v)\,dt + \frac{1}{r^2}\int\cos\omega(t-r/v)\,dt\right]$$

$$= \frac{2I\,dl\cos\theta}{4\pi\epsilon r}\left[\frac{-\omega}{rv}\,\frac{-\cos(\omega(t-r/v))}{\omega} + \frac{1}{r^2}\,\frac{\sin\omega(t-r/v)}{\omega}\right]$$

$$= \frac{2I\,dl\cos\theta}{4\pi\epsilon r}\left[\frac{\cos\omega(t-r/v)}{rv} + \frac{\sin\omega(t-r/v)}{r^2\omega}\right]$$

$$E_\theta = \frac{1}{\epsilon}\int (\nabla \times H)_\theta \, dt$$

$$\therefore E_\theta = \frac{1}{\epsilon}\int \frac{I\,dl \sin\theta}{4\pi r}\left[\frac{-\omega^2 \cos\omega(t-r/v)}{v^2} - \frac{\omega \sin\omega(t-r/v)}{rv} + \frac{\cos\omega(t-r/v)}{r^2}\right] dt$$

$$= \frac{I\,dl\sin\theta}{4\pi\epsilon r}\left\{\frac{-\omega^2}{v^2}\int \cos\omega(t-r/v)\,dt - \frac{\omega}{rv}\int \sin\omega(t-r/v)\,dt + \frac{1}{r^2}\int \cos\omega(t-r/v)\,dt\right\}$$

$$= \frac{I\,dl\sin\theta}{4\pi\epsilon r}\left\{\frac{-\omega^2}{v^2}\left[\frac{\sin\omega(t-r/v)}{\omega}\right] - \frac{\omega}{rv}\left[\frac{-\cos\omega(t-r/v)}{\omega}\right] + \frac{1}{r^2}\cdot\frac{\sin\omega(t-r/v)}{\omega}\right\}$$

$$\therefore E_\theta = \frac{I\,dl\sin\theta}{4\pi\epsilon r}\left[\frac{-\omega}{v^2}\sin\omega(t-r/v) + \frac{1}{rv}\cdot\cos\omega(t-r/v) + \frac{1}{r^2\omega}\sin\omega(t-r/v)\right]$$

$$E_\phi = 0.$$

(P) what distance from the antenna the inductive and radiative fields are equal. ~~[illegible]~~

(A) ~~Radiative field component~~ =

Consider Magnetic field component of EM-wave.

Radiative field component $= \dfrac{-I\,dl\sin\theta\,\omega}{4\pi}\dfrac{\sin\omega(t-r/v)}{rv}$

Inductive " " $= \dfrac{I\,dl\sin\theta}{4\pi}\dfrac{\cos\omega(t-r/v)}{r^2}$

Equate the magnitude of radiative & Inductive components & excluding sine & cos terms because the max. value is one

$v = n\lambda$

$$\frac{\omega}{\cancel{r}v} = \frac{1}{r^{\cancel{2}}} \Rightarrow r = \frac{v}{\omega}$$

$$r = \frac{v}{2\pi f} \Rightarrow \boxed{r = \frac{\lambda}{2\pi}}$$

$$r = \frac{\lambda}{6.18}$$

(f) An Antenna operating at 60Hz frequency; find the distance at which inductive & radiative fields are equal.

Sol

$F = 60\,Hz$.

$C = n\lambda \quad \Rightarrow \lambda = \frac{3\times10^8}{60} \Rightarrow \lambda = 5000\,km$

$r = \frac{\lambda}{6.28} = \frac{5000\,km}{6.28} = \underline{796.17\,km}$

(P) Compare the relationship b/w radiative component of electric & magnetic fields & Hence obtain the expression for intrinsic impedance.

Sol

E_θ:

Radiative Component of Electric field (E_θ) $E_\theta = \frac{I\,dl\,\sin\theta}{4\pi\epsilon}\left[-\frac{\omega}{r v^2}\sin\omega(t - r/v)\right]$

Radial component of magnetic field ($H\phi$) is given by

$$H\phi = \frac{I\,dl\,\sin\theta}{4\pi}\left[\frac{-\omega\sin\omega(t - r/v)}{r v}\right].$$

∴ By definition $\eta = E_\theta / H_\phi$

$$\eta = \frac{\frac{\cancel{I\,dl\,\sin\theta}}{\cancel{4\pi}\epsilon}\left[-\omega/_{rv^2}\cdot\sin\omega(t - r/v)\right]}{\frac{\cancel{I\,dl\,\sin\theta}}{\cancel{4\pi}}\left[-\omega/_{rv}\ \sin\omega(t - r/v)\right]}$$

$$\eta = \frac{1}{v\epsilon}$$ We know that $v = \frac{1}{\sqrt{\mu\epsilon}}$

$$= \frac{1}{1/\sqrt{\mu\epsilon}\cdot\epsilon} \Rightarrow \sqrt{\mu/\epsilon}$$

$$= \underline{377\Omega}$$

Radiation resistance of a current element (short dipole)

General expressions for radiation fields of electric and magnetic fields are

$$E_\theta = \frac{I\,dl\sin\theta}{4\pi}\left[\frac{-\omega\sin\omega t'}{v r}\right] \qquad t' = (t - r/v)$$

$$H_\phi = \frac{I\,dl\sin\theta}{4\pi\epsilon}\left[\frac{-\omega\sin\omega t'}{v^2 r}\right]$$

$\therefore\ P_r = E_\theta \cdot H_\phi$

$$P_r = \left[\frac{I\,dl\sin\theta}{4\pi}\right]^2 \times \frac{\omega^2\sin^2\omega t'}{v^3 r^2 \epsilon} = \left[\frac{\omega I\,dl\sin\theta}{4\pi v r}\right]^2 \cdot \left[\frac{1-\cos 2\omega t'}{2v\epsilon}\right]$$

$$\therefore\ v\epsilon = \frac{1}{\sqrt{\mu\epsilon}}\cdot\epsilon \Rightarrow \sqrt{\epsilon/\mu} = \frac{1}{\eta}$$

$$\therefore\ P_r = \left[\frac{\omega I\,dl\sin\theta}{4\pi v r}\right]^2 \cdot \frac{1-\cos 2\omega t'}{2/\eta}$$

$$P_{r(avg)} = \eta/2 \cdot \left[\frac{\omega I\,dl\sin\theta}{4\pi v r}\right]^2 \times 1 \qquad \because \text{Avg power of } \cos 2\omega t' = 0.$$

$\therefore$ Total Power radiated $= \int_0^\pi P_{r\,avg}\, ds$ $\quad (ds = 2\pi r^2\sin\theta\, d\theta.)$

$$\text{Power radiated} = \int_0^\pi \frac{\eta}{2}\left[\frac{\omega I\,dl\sin\theta}{4\pi v r}\right]^2 \times 2\pi r^2\sin\theta\, d\theta$$

$$= \frac{\eta\omega^2 I^2 dl^2}{16\pi v^2}\int_0^\pi \sin^3\theta\, d\theta$$

$$\int_0^\pi \sin^3\theta\, d\theta = 2\int_0^{\pi/2}\sin^3\theta\, d\theta = 2\left[\frac{3-1}{3}\right] = 4/3$$

$$= \frac{(120\pi)(2\pi f)^2 \cdot I^2 \cdot dl^2}{16\pi (\lambda f)^2} \times 4/3$$

$$\text{Power radiated} = 40\pi^2 I_m^2\left(\frac{dl}{\lambda}\right)^2$$

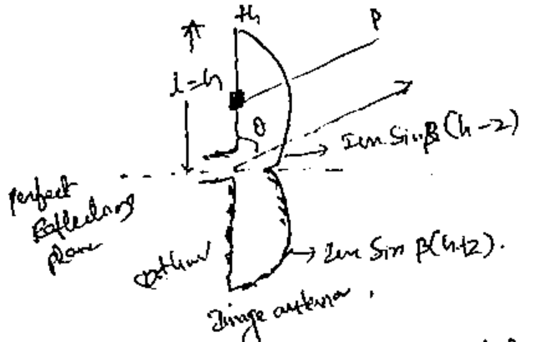
We know that $I_m = \sqrt{2} I_{rms}$

$$R_r = \text{Power radiated} \times I^2_{rms}$$

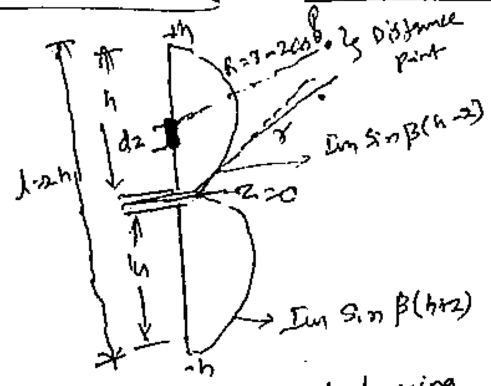
$$\text{Power radiated} = 80\pi^2 \cdot I^2_{rms}\left(\frac{dl}{\lambda}\right)^2$$

$$\text{Radiation Resistance } R_r = 80\pi^2 \cdot \left(\frac{dl}{\lambda}\right)^2$$

Power radiated by half wave dipole & a Quarter wave monopole :



Mono pole having Sinusoidal.



Half wave Dipole having Sinusoidal

Note: Max radiation is normal to the axis.

Consider a current element Idz is placed at a distance z from $z=0$ plane & aligned along z-axis. The current has sinusoidal distribution with a max. value of I_m

The current I is given by

$$I = I_m \sin\beta(h+z) \quad \text{for } z<0$$
$$= I_m \sin\beta(h-z) \quad \text{for } z>0.$$

Due to this current element Idz, vector potential A at point P is

$$dA_z = \frac{\mu I}{4\pi R} e^{-j\beta R} dz \quad \text{— ①}$$

The total vector magnetic potential at distance point is obtained by

$$A_z = \int_{-h}^{h} dA_z$$

$$A_z = \int_{-h}^{h} \frac{\mu I}{4\pi R} e^{-j\beta R} dz$$

$$= \int_{-h}^{0} \frac{\mu I}{4\pi R} e^{-j\beta R} dz + \int_{0}^{h} \frac{\mu I}{4\pi R} e^{-j\beta R} dz.$$

$$\therefore A_z = \int_{-h}^{0} \frac{\mu \cdot I_m \sin\beta(h+z)}{4\pi R} \cdot e^{-j\beta R} dz + \int_{0}^{h} \frac{\mu \cdot I_m \sin\beta(h-z)}{4\pi R} \cdot e^{-j\beta R} dz$$

$$= \cancel{\frac{\mu I_m}{4\pi}} \qquad \text{From figure } R = r - z\cos\theta$$

$$R \simeq r.$$

If put in the Nr $R = r - z\cos\theta$ (because R is involved in phase factor) & in Dr $R \simeq r$.

$$A_z = \frac{\mu I_m}{4\pi r} \int_{-h}^{0} \sin\beta(h+z)\, e^{-j\beta(r - z\cos\theta)} dz + \frac{\mu I_m}{4\pi r} \int_{0}^{h} \sin\beta(h-z) \cdot e^{-j\beta(r - z\cos\theta)} dz$$

$$= \frac{\mu I_m}{4\pi r} \cdot \int_{-h} \sin\beta(h+z) \cdot e \cdot e \; dz + \int_0 \sin\beta(h-z) \; e \; dz$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \int_{-h}^{0} \sin\beta(h+z)\, e^{j\beta z\cos\theta} dz + \int_0^h \sin\beta(H-z) \cdot e^{j\beta z\cos\theta} dz.$$

Consider $\sin\beta(h+z)$ for quarter wave monopole.

$$H = \lambda/4, \quad \beta = \frac{2\pi}{\lambda}$$

$$\sin\beta(h+z) = \sin(\beta h + \beta z)$$

$$= \sin\left[\frac{2\pi}{\lambda} \cdot \lambda/4 + \beta z\right]$$

$$= \cos\beta z.$$

||^{ly} $\sin\beta(h-z) = \cos\beta z.$

$$A_z = \frac{\mu I_m e^{-j\beta r}}{4\pi r} \cdot \int_{-h}^{0} \cos\beta z \cdot e^{j\beta z\cos\theta} dz + \int_0^h \cos\beta z \cdot e^{j\beta z\cos\theta} dz.$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \cdot \int_0^h \cos(-\beta z)\, e^{-j\beta z\cos\theta} dz + \int_0^h \cos\beta z \; e^{j\beta z\cos\theta} dz.$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \cdot \int_0^h \cos\beta z \left[e^{j\beta z\cos\theta} + e^{-j\beta z\cos\theta}\right] dz$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \cdot \int_0^h 2\cos\beta z \cos(\beta z\cos\theta)\, dz$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \cdot \int_0^h \left[\cos(\beta z + \beta z\cos\theta) + \cos(\beta z - \beta z\cos\theta)\right] dz$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \left\{ \left[\frac{\sin(\beta z + \beta z\cos\theta)}{\beta(1+\cos\theta)}\right]_0^h + \left[\frac{\sin\beta z(1-\cos\theta)}{\beta(1-\cos\theta)}\right]_0^h \right\}$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \left[\frac{\sin\beta h(1+\cos\theta)}{\beta(1+\cos\theta)} + \frac{\sin\beta h(1-\cos\theta)}{\beta(1-\cos\theta)}\right]$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r} \left[\frac{(1-\cos\theta)\sin\beta h(1+\cos\theta) + (1+\cos\theta)\sin\beta h(1-\cos\theta)}{\beta(1+\cos\theta)\;\beta(1-\cos\theta)}\right]$$

$$= \frac{\mu I_m e^{-j\beta r}}{} \left[\frac{(1-\cos\theta)\sin\beta h(1+\cos\theta) + (1+\cos\theta)\sin\beta h(1-\cos\theta)}{}\right]$$

consider $\sin\beta h(1+\cos\theta)$

$h = \lambda/4$, & $\beta = 2\pi/\lambda$ $\therefore \sin\beta h(1+\cos\theta) = \cos\frac{\pi}{2}\cos\theta$

$\sin\left[\frac{2\pi}{\lambda}\cdot\frac{\lambda}{4}(1+\cos\theta)\right]$

Mly $\sin\beta h(1-\cos\theta) = \cos\frac{\pi}{2}\cos\theta$. $\Rightarrow \sin\left(\frac{\pi}{2}+\frac{\pi}{2}\cos\theta\right) = \cos\frac{\pi}{2}\cos\theta$

$$\therefore A_z = \frac{\mu I_m e^{-j\beta r}}{4\pi r\beta}\left[\frac{(1-\cos\theta)\cos(\frac{\pi}{2}\cos\theta) + (1+\cos\theta)\cos(\frac{\pi}{2}\cos\theta)}{\sin^2\theta}\right]$$

$$= \frac{\mu I_m e^{-j\beta r}}{4\pi r\beta}\cdot\frac{2\cos(\pi/2\cos\theta)}{\sin^2\theta} \Rightarrow \frac{\mu I_m \cdot e^{-j\beta r}}{2\pi r\beta}\cdot\frac{\cos(\pi/2\cos\theta)}{\sin^2\theta}.$$

By def. $B = \nabla\times A$.

$\mu H = \nabla\times A$.

$H = \frac{1}{\mu}(\nabla\times A)$.

$$H\phi = \frac{1}{\mu}(\nabla\times A)\phi$$

$$= \frac{1}{\mu}\left[\frac{1}{r}\left[\frac{\partial}{\partial r}(rA\theta) - \frac{\partial}{\partial\theta}(Ar)\right]\right]$$

~~we know~~ we know that $A\theta = -A_z \sin\theta$

$Ar = 0.$ ($Ar = A_z\cos\theta$
$= A_z\cos 90°$.

$$H\phi = \frac{1}{\mu}\left[\frac{1}{r}\left[\frac{\partial}{\partial r}(rA\theta)\right]\right]$$

$$= \frac{1}{\mu}\left[\frac{1}{r}\left\{\frac{\partial}{\partial r}(-rA_z\sin\theta)\right\}\right]$$

$$= \frac{1}{\mu}\left\{\frac{1}{r}\left[\frac{\partial}{\partial r}\left(-r\sin\theta\,\frac{\mu I_m e^{-j\beta r}}{2\beta r\pi}\cdot\left(\frac{\cos(\pi/2\cos\theta)}{\sin^2\theta}\right)\right)\right]\right\}$$

$$= \frac{-1}{\mu}\frac{1}{r}\cdot\frac{\mu I_m}{2\pi\beta}\frac{\cos(\pi/2\cos\theta)}{\sin\theta}\cdot\frac{\partial}{\partial r}(e^{-j\beta r})$$

$$H\phi = \frac{-I_m}{2\pi\beta r}\frac{\cos(\pi/2\cos\theta)}{\sin\theta}\cdot -j\beta\cdot e^{-j\beta r}$$

$$H\phi = \frac{jI_m e^{-j\beta r}}{2\pi r}\cdot\frac{\cos(\pi/2\cos\theta)}{\sin\theta} \Rightarrow |H\phi| = \frac{I_m}{2\pi r}\cdot\frac{\cos(\pi/2\cos\theta)}{\sin\theta} \rightarrow$$

By definition $\eta = E\theta/H\phi \Rightarrow E\theta = \eta H\phi$.

$$|E\theta| = 120\pi\cdot\frac{I_m}{2\pi r}\frac{\cos(\pi/2\cdot\cos\theta)}{\sin\theta}$$

$$|E\theta| = \frac{60 I_m}{r}\frac{\cos(\pi/2\cos\theta)}{\sin\theta}.$$

Instantaneous poynting vector $= P_{max} = (E\theta)(H\phi)$.

$$= \frac{60 I_m}{r} \frac{\cos(\pi/2 \cos\theta)}{\sin\theta} \cdot \frac{I_m}{2\pi r} \cdot \frac{\cos(\pi/2 \cos\theta)}{\sin\theta}$$

$$= \frac{30 I_m^2}{\pi r^2} \cdot \frac{\cos^2(\pi/2 \cos\theta)}{\sin^2\theta}$$

But Avg. power is $P_{avg} = \frac{P_{max}}{2}$

$$= \frac{15 I_m^2}{\pi r^2} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right]^2$$

But $I_{rms} = \frac{I_m}{\sqrt{2}}$

$I_m = \sqrt{2} I_{rms}$.

$$P_{avg} = \frac{15 (I_{rms}\sqrt{2})^2}{\pi r^2} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right]^2$$

$$= \frac{30 I_{rms}^2}{\pi r^2} \left(\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right)^2.$$

Total radiated power is obtained by integrating the above eq. over closed surface

$$P_{rad} = \oint_s P_{avg}\, ds$$

$$P_{rad} = \oint_s \frac{30 I_{rms}^2}{\pi r^2} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right]^2 ds.$$

By def. elemental surface is defined as $ds = 2\pi r \sin\theta \, r d\theta$

$$\therefore P_{rad} = \oint_s \frac{30 I_{rms}^2}{\pi r^2} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right]^2 \cdot 2\pi r^2 \sin\theta \, d\theta$$

$$= 60 I_{rms}^2 \oint_s \frac{\cos^2(\pi/2 \cos\theta)}{\sin\theta} \, d\theta$$

~~for~~ ~~all~~ ~~quarter~~

Then the radiated power $= 60 \cdot I_{rms}^2 \underbrace{\int_0^{\pi} \frac{\cos^2(\pi/2 \cos\theta)}{\sin\theta} \, d\theta}_{\text{Using Simpson's rule} = 1.218}$

$$\therefore P_{rad} = 60 \times I_{rms}^2 \times 1.218$$

$$P_{rad} = 73.08\, I_{rms}^2$$

$\therefore$ Radiation resistance $= \underline{73\,\Omega}$ (Half Dipole)

(P) Define directivity. obtain the directivity of an isotropic antenna, short dipole & half wave dipole

Sol

Directivity of antenna is given by ratio of its max. radiation intensity to the average radiation intensity of an isotropic antenna.

$$D = \frac{U_{max}}{U_{av}} = \frac{\text{Max. radiation intensity}}{\text{Avg. radiation intensity}}.$$

∴ Directivity (D) interms of total power radiated is

$$D = \frac{4\pi \times \text{Maximum radiation intensity}}{\text{Total power radiated.}}$$

$$D = \frac{4\pi \times U_{max}}{W_T} \qquad \because U_{avg} = \frac{W_T}{4\pi}.$$

Directivity of an Isotropic Antenna

$$D = \frac{\text{Radiation intensity of required antenna}}{\text{Radiation intensity of of isotropic anna}} = \frac{U}{U_0}$$

∵ required antenna is a isotropic antenna $U = U_0$

∴ Directivity $D = \frac{U_0}{U_0} = 1$

Directivity of a Short Dipole

$$D = \frac{P_{max}}{P_{avg}}.$$

we know that $P = \frac{30\pi I_0^2 L^2 \sin^2\theta}{\lambda^2 r^2}$

∴ P_{max}. is obtained by putting $\theta = 90^\circ$

$$\therefore P_{max} = \frac{30\pi I_0^2 L^2}{\lambda^2 r^2}.$$

$$P_{avg} = \frac{P_t}{4\pi r^2} = \frac{I_0^2 R_r}{4\pi r^2}$$

$$R_r = 80\pi^2 \frac{L^2}{\lambda^2}$$

$$\Rightarrow P_{avg} = \frac{80\pi^2 L^2 \cdot I_0^2}{4\pi r^2 \lambda^2} = \frac{80\pi L^2 I_0^2}{4 r^2 \lambda^2} = \frac{20\pi L^2 I_0^2}{r^2 \lambda^2}$$

$$D = \frac{P_{max}}{\ldots} = \frac{30\pi I_0^2 L^2}{\lambda^2 r^2} \ldots = 1.5$$

$$P_{max} = \frac{30 I_m^2}{\pi r^2} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta} \right]^2$$

$$P_{max} = \frac{30 I_m^2}{\pi r^2} \left[\frac{\cos 0}{1} \right]$$

$$= \frac{30 I^2}{\pi r^2}$$

$$P_{avg} = \frac{P_t}{4\pi r^2}$$

$$= \frac{I_0^2 R_r}{4\pi r^2} = \frac{I_0^2 73}{4\pi r^2}$$

$$\therefore \text{Directivity} = \frac{\frac{30 I^2}{\pi r^2}}{\frac{I_0^2 73}{4\pi r^2}} = \frac{120 I^2}{73 I^2} = \underline{\underline{1.64}} = \underline{\underline{2.15\,dB}}$$

→ Find the effective length of a half wave dipole :

$$\text{Effective } \cancel{\text{volt}} \text{ length } l_e = \frac{\text{Induced voltage}}{\text{Incident field strength}}$$

$$\Rightarrow l_e = \frac{V}{E}$$

$$l = 2\sqrt{\frac{A_e R_r}{Z_0}}$$

$$= \frac{\lambda^2}{\Omega_A}$$

$$A_e = \frac{D \cdot \lambda^2}{4\pi} = \frac{1.64 \lambda^2}{4\pi} = \underline{\underline{0.13 \lambda^2}}$$

$$= 2\sqrt{\frac{0.13057 \times 73}{120\pi}} = 2 \times 0.159$$

$$l_e = \underline{\underline{0.318}} \lambda$$

— Find the Aepertive area of a short dipole.

Sol

$$A_e = \frac{V^2}{4 S R_r} \qquad \because A_e = \frac{P}{S} \qquad P = \frac{V^2}{4R_r}$$

$$S = E^2/\eta .$$

$$V = El .$$

$$\Rightarrow A_e = \frac{\eta \cancel{E^2} l^2}{4 \times \cancel{E^2} \times R_r} \Rightarrow \frac{\eta l^2}{4 \times R_r}$$

$$A_e = \frac{\eta\, l^2}{4 \times 80\pi^2 \times \frac{l^2}{\lambda^2}}$$

$$= \frac{\eta \lambda^2}{4 \times 80\pi^2} \Rightarrow \frac{120\pi \times \lambda^2}{4 \times 80 \times \pi^2}$$

$$A_e = \frac{3}{8\pi}\lambda^2$$

$$A_e = 0.1194\lambda^2$$

$$D = \frac{4\pi}{\lambda^2} A_e$$

$$\Rightarrow A_e = \frac{D\lambda^2}{4\pi}$$

(P) Find the effective length of a half wave dipole.

$$l = 2\sqrt{\frac{A_e R_r}{\eta_0}} = 0.318\lambda$$

(P) Define the effective aperture & Calculate the effective aperture of 0.25λ dipole.

$D = 3.28$ (λ/4 mono pole)

Sol

$$A_e = \frac{l^2 \eta_0}{4 R_r} = \frac{l \times \eta}{4 \times 36.5} = \frac{l^2 \times \eta}{146}$$

$$A_e = l^2 \times 2.58$$

$$= \frac{\lambda^2 \times 2.58}{16} = 0.16\lambda^2$$

$$D = \frac{4\pi}{\lambda^2} \times A_e$$

$$A_e = \frac{D\lambda^2}{4\pi} = \frac{3.28\lambda^2}{4\pi} = 0.261\lambda^2$$

(P) Derive the relation ship b/w the effective aperture & and directivity of antenna.

Sol

$D_1 \propto A_{e1}$, $\quad \frac{D_1}{D_2} = \frac{A_{e1}}{A_{e2}}$

$D_2 \propto A_e$

If antenna 1 is isotropic antenna, then $D_1 = 1$

$$\Rightarrow \frac{1}{D_2} = \frac{A_{e1}}{A_{e2}} \Rightarrow D_2 = \frac{A_{e2}}{A_{e1}}$$

Let us consider a short dipole antenna,

$$D_2 = 3/2, \quad A_e = \frac{3}{8\pi}\lambda^2$$

$$A_{e1} = \frac{(3/8\pi)\lambda^2}{3/2}$$

$$A_{e1} = \lambda^2/4\pi$$

$$\therefore D_2 = \frac{A_{e2}}{A_{e1}}$$

$$\Rightarrow A_{e2} = D_2 \cdot \frac{\lambda^2}{4\pi}$$

$$\therefore \boxed{D_2 = A_e \cdot \frac{4\pi}{\lambda^2}}$$

(P) The radiation intensity of a particular antenna is given by $\phi(\theta,\phi) = \sin^2\theta$. Calculate the directivity of antenna.

Sol From the given radiation intensity $\phi(\theta=\phi) = \sin^2\theta$, the max. radiation intensity is $\phi_m = 1$.

Then the total power radiated is

$$P_{rad} = \int \sin^2\theta \, ds = \int_0^{\pi} \sin^2\theta \cdot 2\pi r^2 \sin\theta \, d\theta$$

$$= 2\pi r^2 \int \sin^3\theta \, d\theta = 4/3 \times 2\pi r^2 = \frac{8\pi}{3} r^2.$$

$$\therefore P_{Avg} = \frac{P_T}{4\pi r^2} = \frac{8\pi/3\, r^2}{4\pi r^2} = 2/3.$$

$$\therefore \text{Directivity} = \frac{\text{Max. power radiated}}{\text{Avg. power radiated}} = \frac{1}{2/3} = 3/2$$

(P) Calculate the power gain of half wave dipole whose ohmic losses & directive gain are 7Ω & 1.64 respectively

Sol The antenna efficiency $\eta = \frac{G_P}{G_d}$

But

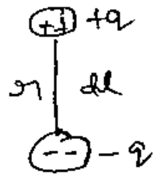
$$\eta = \frac{R_r}{R_r + R_l} \Rightarrow \frac{G_P}{1.64} = \frac{73}{73+7}$$

Hertzian Dipole.

It is defined as the smallest part of the current element, where the current is differant which forms building blocks for practical antenna.

Consider the current flowing through Hertzian dipole is defined

$$i = I\cos\omega t$$



The relationship b/w charge accumilated & current flow

$$i = \frac{dq}{dt}$$

$$\int dq = \int i\,dt$$

$$q = \int i\,dt$$

$$q = \int I\cos\omega t \Rightarrow \frac{I\sin\omega t'}{\omega} \quad \text{—}⑧$$

By definition r-component of E-field for a current element is

$$E_r = \frac{2Idl\cos\theta}{4\pi\epsilon}\left[\frac{\cos\omega t'}{r^2 v} + \frac{\sin\omega t'}{r^3\omega}\right]$$

Similarly θ- component of E-field for current element

$$E_\theta = \frac{Idl\sin\theta}{4\pi\epsilon}\left[\frac{-\sin\omega t'}{v^2 r} + \frac{\cos\omega t'}{r^2 v} + \frac{\sin\omega t'}{r^3\omega}\right]$$

The electrostatic field for r-component of field is the one that varies inverse with cube of distance

$$E_r = \frac{2Idl\cos\theta}{4\pi\epsilon}\left[\frac{\sin\omega t'}{r^3\omega}\right]$$

$$= \frac{I\sin\omega t'}{\omega}\ \frac{2dl\cos\theta}{4\pi\epsilon r^3}$$

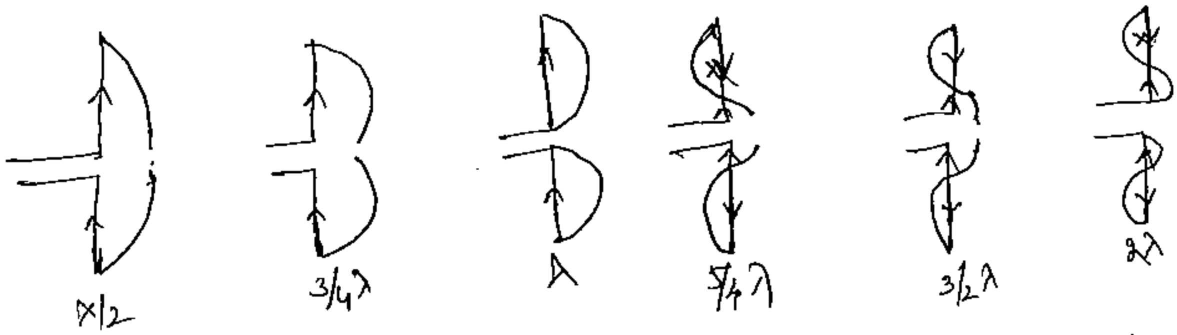
$$\therefore E_r = \frac{2q\,dl\cos\theta}{4\pi\epsilon r^3} \longrightarrow$$ This equation represents the electrostatic field component for r-component of electric field for a Hertzian dipole.

The Electrostatic field component for θ- component of E-field for current element

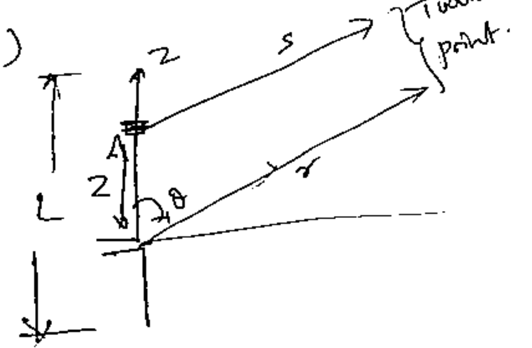
$$E_\theta = \frac{I\sin\omega t'}{\omega}\ \frac{Idl\sin\theta}{4\pi r^3} \Rightarrow \frac{q\,dl\sin\theta}{4\pi\epsilon r^3}.$$

The Antennas are Symmetrically fed at the center by a balanced two wire transmission line. The antennas may be of any length; but it is assumed that the current distribution is sinusoidal.

Examples of the approximate natural-current distributions on a number of thin, linear center fed antennas of different length are shown below.



The value of the current at any point z on the antenna referred to a point at a distance s is



$$[I] = I_0 \sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm z\right)\right] \cdot e^{j\omega(t - r/v)}$$

where $\sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm z\right)\right]$ is form factor for the current on the antenna.

The expression $\frac{L}{2} + z$ is used when $z < 0$
$\frac{L}{2} - z$ is used when $z > 0$

Far fields of center fed dipole

$$H_\phi = \frac{j[I_0]}{2\pi r}\left[\frac{\cos\left[(\beta L \cos\theta)/2\right] - \cos(\beta L/2)}{\sin\theta}\right]$$

$$E_\theta = \frac{j60[I_0]}{r}\left[\frac{\cos\left[(\beta L \cos\theta)/2\right] - \cos(\beta L/2)}{\sin\theta}\right]$$

where $[I_0] = I_0 e^{j\omega(t - r/v)}$

&

$E_\theta = 120\pi H_\phi$

when $L = \lambda/2$ the pattern factor becomes.

$$E = \frac{\cos\left[\frac{\pi}{2}\cos\theta\right]}{\sin\theta}$$

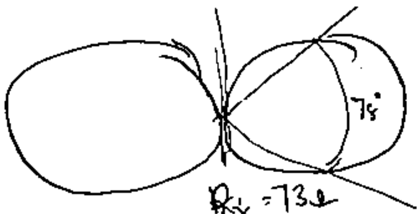
$L = \lambda$, the pattern factor becomes

$$E = \frac{\cos(\pi\cos\theta) + 1}{\sin\theta}$$

$L = 3\lambda/2$, the pattern factor becomes.

$$E = \frac{\cos\left(\frac{3}{2}\pi\cos\theta\right)}{\sin\theta}$$

patterns of the Antennas

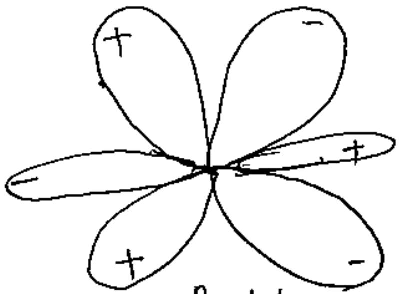


$R_r = 73\Omega$

$\lambda/2$ antenna

$R_r = 200\Omega$

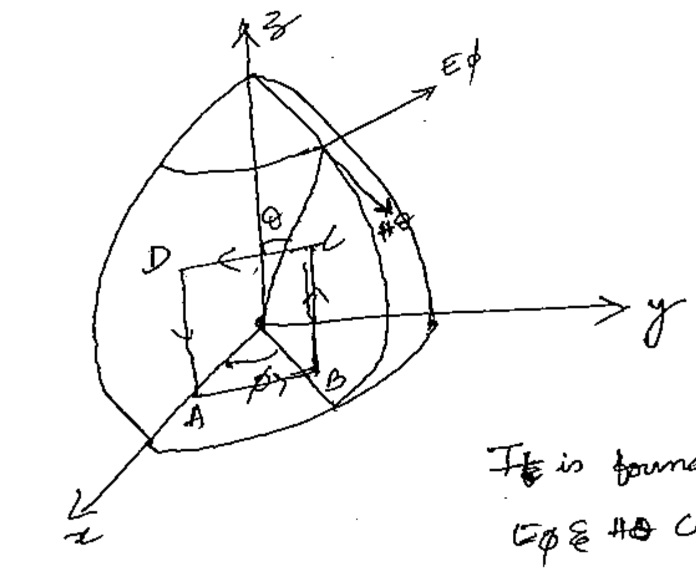
λ antenna



$R_r = 106\Omega$

$3\lambda/2$ antenna.

$$A = \frac{V^2}{USRN}$$



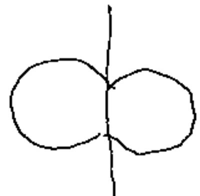
Each side of the square will act as a Dipole.

∴ However we consider AD, BC dipoles for analysis.

Because of Voltages induced in horizontal arms AB & DC is zero

It is found that the far field will have $E\phi$ & $H\theta$ components.

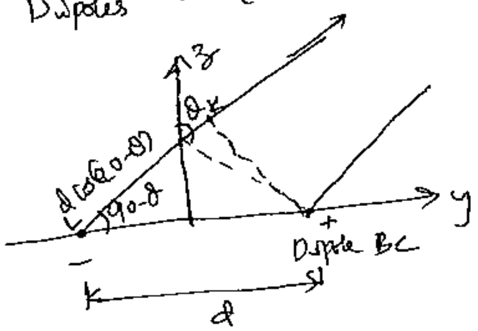
However in Vertical the radiation pattern exhibits the radiation pattern of an isotropic antenna.



Radiation pattern in Horizontal plane (X Y plane)

Radiation pattern in Vertical plane (or) YZ plane

Dipoles AD & BC placed in YZ plane is shown in fig.



The radiation from dipole BC will reach the distant point much early compare to radiation from dipole AD, because the path difference KL

∴ Path difference $= d\cos(90-\theta)$.

The path difference in terms of wave length $= \frac{d}{\lambda}\cos(90-\theta)$.

then Phase difference $\psi = 2\pi \times$ path difference

$= 2\pi \times \frac{d}{\lambda}\sin\theta$ $\quad \because \cos(90-\theta) = \sin\theta$

$= \beta d \sin\theta$.

the electric field component due to dipole = magnitude $e^{j(\text{Phase difference})}$

$E\phi_1$ is E-field at distance point ... ...

$$E\phi_1 = -E_0 \cdot e^{j\psi/2}$$

& $E\phi_2 = E_0\, e^{-j\psi/2}$ $\quad E\phi_2 \rightarrow$ due to BC

$$\therefore E\phi = E\phi_1 + E\phi_2$$

$$E\phi = -E_0\, e^{j\psi/2} + E_0\, e^{-j\psi/2}$$

$$= -2j\, E_0 \sin \psi/2$$

$$\therefore E\phi = -2j\, E_0 \sin\left[\frac{\beta d \sin\theta}{2}\right]$$

we know that $\eta = \frac{-E\phi}{H\theta}$ $\Rightarrow H\theta = -\frac{E\phi}{\eta}$

$$\therefore H\theta = -\frac{1}{\eta}\left[-2j\, E_0 \sin\left[\frac{\beta d \sin\theta}{2}\right]\right]$$

$$= \frac{j}{60\pi} E_0 \sin\left[\frac{\beta d \sin\theta}{2}\right].$$

Here E_0 represents the amplitude of E-field component & is defined by

$\therefore$ The max. value of $\sin\theta = 1$

$$E_0 = \frac{j60\pi IL\sin\theta}{r\lambda} = j\,\frac{60\pi IL}{r\lambda}$$

$$H\theta = \frac{j}{60\pi} \times \frac{j60\pi IL}{r\lambda} \sin\left[\frac{\beta d \sin\theta}{2}\right]$$

$$= \frac{-IL}{r\lambda} \cdot \frac{\beta d \sin\theta}{2}$$

$\because \frac{\beta d \sin\theta}{2}$ is small then $\sin\left(\frac{\beta d \sin\theta}{2}\right) = \frac{\beta d \sin\theta}{2}$

Since $L = d$ $\quad \beta = 2\pi/\lambda$.

$$H\theta = \frac{-Id^2\pi \sin\theta}{r\lambda^2}$$

& $E\phi = -\eta H\theta$

$$E\phi = +\frac{\eta\, Id^2\pi \sin\theta}{r\lambda^2}$$

Radiation resistance of loop antenna

Avg. Radiated power $P_{r\,avg} = P = \frac{1}{2}|E \times H|$

$$= \frac{1}{2} E \times \frac{E^2}{\eta}$$

$$= \frac{1}{2}|E^2/\eta|$$

$$P_{avg} = \left[\frac{\eta \pi A I_0 \sin\theta}{\lambda^2 r}\right]^2 \times \frac{1}{2\eta} = \frac{\eta}{2}\left[\frac{\pi A}{\lambda^2 r}\right]^2 I_0^2 \sin^2\theta.$$

$\therefore$ ~~Max power~~ =

Total power radiated is $P_{rad} = \oint_S P_{r\,avg} \cdot ds$

$$= \int_0^{\pi} \frac{\eta}{2}\left[\frac{\pi A}{\lambda^2 r}\right]^2 I_0^2\, 2\pi r^2 \sin\theta\, d\theta$$

$$= \frac{\eta}{2}\left[\frac{\pi A}{\lambda^2}\right]^2 \cdot I_0^2 \times 2\pi \int_0^{\pi} \sin^3\theta\, d\theta$$

$$P_{rad} = \frac{4}{3} \times \eta \pi^3 \left[\frac{A}{\lambda^2}\right]^2 I_0^2.$$

$$P_{rad} = 4/3 \times \eta\, \pi^3 \left[\frac{A}{\lambda^2}\right]^2 \times \left[\sqrt{2}\, I_{rms}\right]^2$$

$$= 4/3 \times 120\pi \times \pi^3 \times 2 \times \left[\frac{A}{\lambda^2}\right]^2 \times I_{rms}^2$$

$$= 320\pi^4 \left[\frac{A}{\lambda^2}\right]^2 \times I_{rms}^2$$

$$\therefore R_{rad} = 320\pi^4 \left[A/\lambda^2\right]^2 \times I_{rms}^2.$$

Field equations for Loop antenna (Circular).

$$E_\phi = \frac{60\pi\beta[I]a}{r} J_1(\beta a \sin\theta)$$

$$H_\theta = \frac{\beta[I]a}{2r} J_1(\beta a \sin\theta).$$

For small Loop $\quad J_n(x) = \frac{x^n}{n\, L 2^n}$

$$J_1(x) = \frac{x}{L2} = \frac{x}{2}$$

$$\therefore E_\phi = \frac{60\pi \beta [I] a}{r} J_1(\beta a \sin\theta)$$

$$= \frac{60\pi \beta a [I]}{2r} \beta a \sin\theta = \frac{60\pi (\beta a)^2 [I] \sin\theta}{2r}$$

$$= \frac{120\pi^2 \cdot I \sin\theta \cdot A}{r \lambda^2} \qquad A = \pi r^2$$

$$H_\theta = \frac{\pi \cdot [I] \sin\theta}{r} \frac{A}{\lambda^2}$$

Radiation Resistance of loop antennas

Avg. power $P = \frac{1}{2} E \times H$

$$P_r = \frac{1}{2} H^2 \eta$$

$$P_a = \frac{1}{2} \times 120\pi \times \left(\frac{\beta a I_m}{2r}\right)^2 \cdot J_1(\beta a \sin\theta)^2$$

$$= \frac{1}{2} \times 120\pi \times \left(\frac{\beta a I_m}{2r}\right)^2 \times J_1^2(\beta a \sin\theta)$$

$$P_r = 15\pi (\beta a I_m)^2 \frac{J_1^2(\beta a \sin\theta)}{r^2}$$

Total power radiated is

$$P_{total\ rad} = \oint P_r ds$$

$$= \int_0^\pi \frac{15\pi (\beta a I_m)^2}{r^2} \cdot (J_1^2(\beta a \sin\theta)) \times 2\pi r^2 \sin\theta \, d\theta$$

$$P_r = 30\pi^2 (\beta a I_m)^2 \cdot \int_0^\pi J_1^2(\beta a \sin\theta) \cdot \sin\theta \, d\theta.$$

For Small Loop $J_1(x) = x/2$

$$\therefore J_1^2(\beta a \sin\theta) = \left[\frac{\beta a \sin\theta}{2}\right]^2$$

$$\therefore P_r = 30\pi^2 (\beta a I_m)^2 \int_0^\pi \left[\frac{\beta a \sin\theta}{2}\right]^2 \sin\theta \, d\theta$$

$$= 30\pi^2 (\beta a I_m)^2 \left(\frac{\beta a}{2}\right)^2 \int_0^\pi \sin^3\theta \, d\theta$$

$$= 30\pi^2 (\beta a)^4 \times \frac{1}{4} \times I_m^2 \times 4/3$$

$$= 10\pi^2 \times (\beta a)^4 \times I_m^2$$

$$= 20\pi^2 (\beta a)^4 \times I_{rms}^2$$

$$= \pi^2 \times \beta^4 \times (\pi a^2)^2 \times I_{rms}^2 = 20\pi^2 \beta^4 A^2 I_{rms}$$

$$= 20\left(\frac{2\pi}{\lambda}\right)^4 \times (\pi a^2)^2.$$

$$= 20\pi^2 a^4 \times \left(\frac{2\pi}{\lambda}\right)^4$$

$$R_r = 20\pi^2\left(\frac{2\pi a}{\lambda}\right)^4 \Rightarrow 20\pi^2\left(\frac{C}{\lambda}\right)^4$$ where $C = 2\pi a$

For Large loop

$$P = 30\pi^2(\beta I_m a)^2 \int_0^{\pi} J_1^2(\beta a \sin\theta)\sin\theta\, d\theta$$

$$\int_0^{\pi} J_1^2(x\sin\theta)\sin\theta\, d\theta = \frac{1}{x}\int_0^{2x} J_2(y)\, dy.$$

when $C/\lambda \geq 5$ ie large loop.

$$\int_0^{\pi} J_1^2(\beta a\sin\theta)\sin\theta\, d\theta = \frac{1}{\beta a}\int_0^{2\beta a} J_2(y)\, dy = \frac{1}{\beta a}\cdot 1$$

$$\left(\because \int_0^{2\beta a} J_2(y)\,dy = 1\right)$$

$$\therefore P = 30\pi^2(\beta a I_m)^2 \times \frac{1}{\beta a}$$ where y is any function.

$$= 30\pi^2 I_m^2 \cdot \beta a$$

$$= 30\pi^2 \times (\sqrt{2}\, I_{rms})^2 \times \frac{2\pi}{\lambda} \times a$$

$$=$$

$$\therefore R_r = 60\pi^2\, C/\lambda$$

Directivity of Loop antennas

$$D = \frac{\text{Max. Power radiated } f}{\text{Avg. ~~power~~ radiated power.}}$$

$$P_r = \left[\frac{15\pi(\beta a I_m)^2 J_1^2(\beta a \sin\theta)}{r^2}\right]_{max.}$$

$$\text{Avg. power} = \frac{P_t}{4\pi r^2} =$$

$$P_r = \eta\left[\frac{\beta a I}{2r}\right]^2 J_1(\beta a \sin\theta)^2$$

$\because J_1(\beta a \sin\theta) = \frac{\beta a \sin\theta}{2}$ for small loop

$$= \eta\frac{(\beta a)^2}{4r^2} \times I^2 \times \left(\frac{\beta a \sin\theta}{2}\right)^2$$

$$P_{r\,max} = \frac{\eta(\beta a)^4 \times I^2}{16r^2} \quad \because \sin^2\theta = 1$$

$$\text{Avg. Power} = \frac{P_t}{4\pi r^2} = \frac{I^2 R_r}{4\pi r^2}$$

$$= \frac{20\beta^4 \times (\pi a^2)^2 \times I^2}{4\pi r^2}$$

$$\therefore D = \frac{\dfrac{\eta \times (\beta a)^4 \times I^2}{4\cdot 16 r^2}}{\dfrac{20 \times \beta^4 \times \pi^2 \times a^4 \times I^2}{4\pi r^2}} = \frac{\eta \times \cancel{\beta^4} \times \cancel{a^4}}{4 \times 20 \times \cancel{\beta^4} \times \pi \times \cancel{a^4}} = \frac{3\cancel{120\pi}}{{}_2\cancel{80\pi}} = 3/2$$

$$\therefore D = \underline{3/2}$$

$C/\lambda \geq 1.84$

$J_1(\beta a \sin\theta) = 0.584$

(3) A magnetic field strength of 5 μA/m is required at a point on $\theta = \pi/2$, 2 km away from an Antenna in free space. Neglecting ohmic loss, how much power must the antenna transmit if it is a Hertzian Dipole of Length $\lambda/25$.

Sol

$$|H_\phi| = \frac{I_m \, dL \sin\theta}{2\lambda r}$$

$dL = \lambda/25$

$H_\phi = 5 \mu A/m$

$= 5 \times 10^{-6}$.

$\theta = \pi/2$

$r = 2km$

$$I_m = \frac{2\lambda r \times H_\phi}{dL \sin\theta} = \frac{5 \times 10^{-6} \times 2 \times \lambda \times 2 \times 10^{3}}{\lambda/25 \times \sin \pi/2}$$

$$= \frac{125 \times 4 \times 10^{3} \times 10^{-6}}{1} = \underline{0.5\,A}.$$

$$I_{rms} = \frac{0.5}{\sqrt{2}} = 0.3535$$

$$P_r = 80\pi^2 \cdot \left[\frac{dL}{\lambda}\right]^2 \cdot I_{rms}^2$$

$$= 80\pi^2 \times \left[\frac{\lambda/25}{\lambda}\right]^2 \times (0.3535)^2 = \underline{0.1577\,W}.$$

$\boxed{P_r = 157.7\,mW}$

(4) An electric field strength 10 μA/m² is to be measured at an observation point $\theta = \pi/2$, 500 km from a half wave Dipole antenna operating at 50 MHz

(1) what is the length of dipole

(2) Calculate the Current that must be fed to the antenna

(3) Find the Avg power radiated by the antenna.

Sol (1) $L = \lambda/2$ $\qquad \lambda = \frac{3 \times 10^{8}}{50 \times 10^{6}} = 6$ $\qquad \therefore L = 3m$

(2) $$E_\theta = \frac{60 I_m}{r} \left[\frac{\cos(\pi/2 \cos\theta)}{\sin\theta}\right]$$

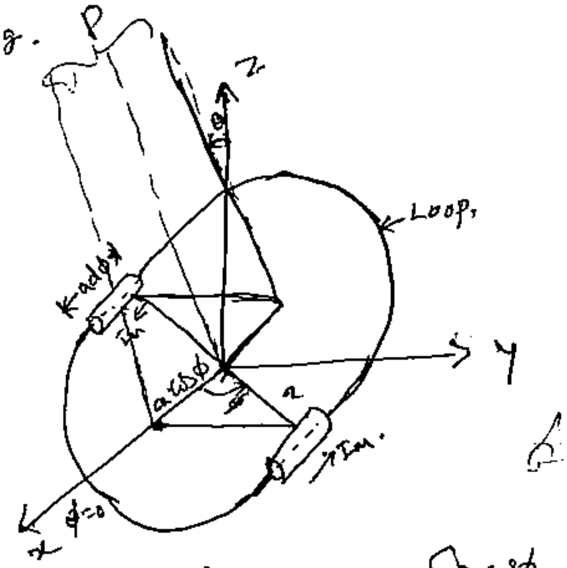
$\therefore I_m = \underline{0.0833\,A} = 83.33\,mA$

(3) $P_{avg} = P_{rad} \cdot I_{rms}^2$.

$P_{Avg} = \underline{253.44 m W}$.

Loop Antenna - General case (Circular loop)

Let the radius of the loop is located with its centre at the origin of the coordinates as shown in fig.
The length of the dipole is $a\,d\phi$



Here only A_ϕ is present
A_r, A_θ is zero.

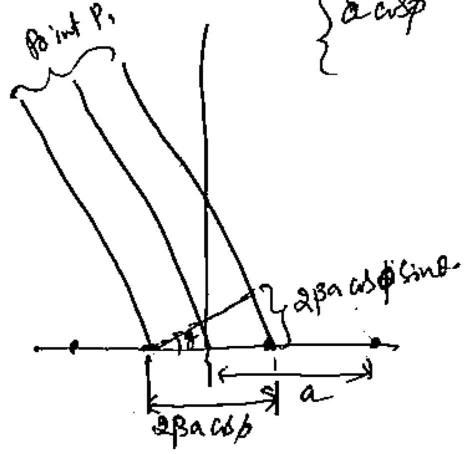
At the point 'P' the ϕ component of A is

$$dA_\phi = \frac{\mu\, dM}{4\pi r}$$

where dM is current moment due to one pair of diametrically opposed dipoles of length $a\,d\phi$.

In the $\phi = 0$ plane, ϕ component of the retarded current moment due to one dipole is $[I]\,a\,d\phi\cos\phi$

$$[I] = I \cdot e^{j\omega(t - r/v)}$$



The resultant moment dM at a large distance due to a pair of diametrically opposed dipoles is

$$dM = 2j[I]\,a\,d\phi\cos\phi\,\sin\psi/2.$$

$$\therefore dM = 2j[I]a\,d\phi\,[\sin(\beta a\cos\phi\sin\theta)]\,d\phi.$$

$$dM = -[I]\,a\,d\phi\cos\phi\, e^{j\psi/2} + [I]a\,d\phi\cos\phi\, e^{-j\psi/2}$$
$$= -[I]\,a\,d\phi\cos\phi\,[e^{j\psi/2} - e^{-j\psi/2}]$$
$$= [I]\,a\,d\phi\cos\phi \cdot 2j\sin\psi/2.$$

then

$$\therefore A_\phi = \frac{j\mu[I]a}{2\pi r}\int_0^{\pi} \sin(\beta a\cos\phi\sin\theta)\cos\phi\, d\phi.$$

$$\therefore A_\phi = \frac{j\mu[I]a}{2r}\, J_1(\beta a\sin\theta).$$

Then the Far Electric field of the loop has only a ϕ component is given by $E_\phi = -j\omega A_\phi$

$$= -j\omega \times \frac{j\mu[I]a}{2r}\, J_1(\beta a\sin\theta)$$

$$= \ldots \qquad \frac{60\pi\,\beta a\,[I]}{\ldots}\, J_1(\beta a\sin\theta)$$

An Antenna (or) Aerial is a system of elevated conductors which couples (or) matches the transmitter or receiver to free space.

A transmitting antenna connected to a transmitter by a transmission line, forces electromagnetic waves into freespace.

A receiving antenna connected to a radio receiver, receives a portion of electromagnetic waves travelling through space.

Radiation pattern:

Radiation pattern of an antenna is nothing but a graph which shows the variation in actual fieldstrength of electromagnetic field at all points which are at equal distance from the antenna.

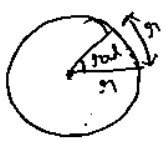
If the radiation from the antenna is expressed in terms of field strength (E), the radiation pattern is called as the "field strength pattern".

Radiation Intensity:

Radiation intensity is defined as power per unit solid angle.

Units of radiation intensity is watts/steradian (or) watts/radian²

Radian & Steradian:



One radian is defined as the plane angle with its vertex at the centre of circle of radius 'r' & subtended by an arc whose length is 'r'.

→ One steradian is defined as, the solid angle with its vertex at centre of a sphere of radius r.

Area of spere $= 4\pi r^2$

$\therefore$ There are 4π steradian in a closed sphere $\left(\text{ie } \frac{4\pi R^2}{R^2}\right)$

— The infinitesimal (extremely small) area ds on a surface of spere of radius r is $\quad ds = r^2 \sin\theta \, d\theta \, d\phi$.

So the element of solidangle $d\Omega$ of a sphere is

$\sin\theta\, d\theta\, d\phi$

Max. Radiation intensity from a reference antenna with same power point

(or) Gain = $\frac{\text{Max. Power received from given antenna } (P_1)}{\text{Max. power received from reference antenna } (P_2)}$.

Directivity (D) :

The Max. directive gain is called as directivity of an antenna & it is denoted by D.

$$D = \frac{\text{Max. Radiation intensity of test antenna.}}{\text{Avg. Radiation Intensity of test antenna.}}$$

$$D = \frac{\phi(\theta,\phi)_{max}}{\phi_{av}}$$ both of test antenna

(or)

$$D = \frac{\text{Power radiated from a test antenna}}{\text{power radiated from an Isotropic antenna.}}$$

Directive gain (Gd) :

$$G_d = \frac{\text{Radiation Intensity in a particular direction}}{\text{Avg. radiated power}}$$

Antenna efficiency (η)

The efficiency of antenna is defined as the ratio of power radiated to the total i/p power supplied to the antenna.

$$\eta = \frac{\text{Power Radiated}}{\text{Total I/p power.}}$$

Effective area (or) Effective aperture (or) capture area:

$$\text{Effective area} = \frac{\text{Power received at the antenna load terminal}}{\text{Power density (Poynting vector).}}$$

$$A_e = \frac{W_r}{P}$$ $\boxed{\text{Power density} = W/m^2}$

Antenna Beam width ;

It is a Measure of directivity of an antenna. Antenna Beam width is an angular width in degrees, measured on the radiation pattern b/w points where the radiated power has fallen to half its max. value. This is called as "beam width" b/w half power point (or) half power beam width (HPBW), because power at half power points is just half. This is also known as 3dB beam width.

A antenna defined as the structure associated with the region of transition between a guided wave and free space wave (or) vice versa.

Transmitting antenna is a region of transition from guided wave on a transmission line to freespace.

Receiving antenna is a region of transition from a space wave to a guided wave on transmission line.

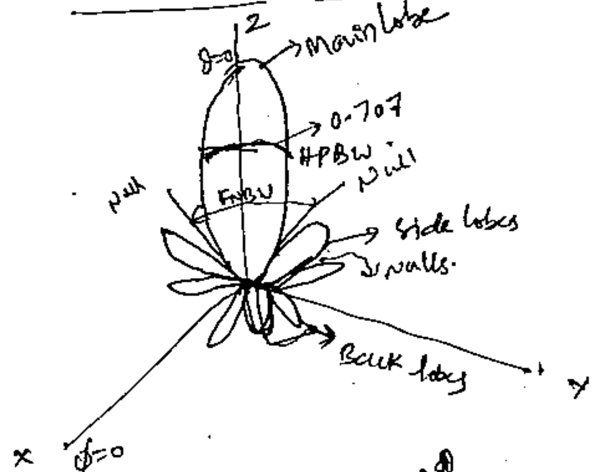
Pattern

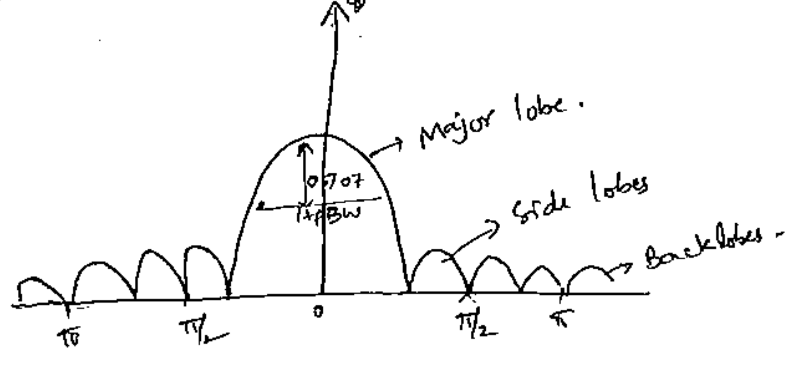
Radiation pattern of an antenna is nothing but a graph which shows the variation in actual field strength of electromagnetic field at all points ~~each~~ ~~at~~.

~~Radiation pattern of a~~

If the radiation from the antenna is expressed in terms of field strength (E), the radiation pattern is called as "Field pattern".

Three dimentional field pattern





Major lobe → It is called as main beam & is defined as the radiation lobe containing the direction of max. radiation.

Minor lobe: It is any lobe except a major lobe. i.e all lobes except major lobe.

Side lobe: Normally a side lobe is adjacent to the main lobe.

Back lobe: Normally refers to minor lobe the occupies the hemisphere in a direction opposite to that of major lobe.

Antenna Beam width:

It is a measure of directivity of an antenna. Antenna Beam width is an angular width in degrees, measured on the radiation pattern.

The angular beam width at the half power level is called Half power beam width "HPBW"

The Beam width at first Nulls is called "FNBW" (First Beam width first Nulls. (FNBW).

(P) An Antenna has a field pattern given by $E(\theta)\cos^2\theta$. for $0 \leq \theta \leq 90°$. Find HPBW.

Sol $E(\theta)$ at half power $= 0.707$

Thus $0.707 = \cos^2\theta \Rightarrow \cos\theta = \sqrt{0.707}$

$\theta = 33°$.

$HPBW = \underline{66°}$ (2θ)

(P) An Antenna has a field pattern given by $E(\theta) = \cos\theta \cos 2\theta$ for $0 \leq \theta \leq 90°$

find (a) HPBW (b) FNBW.

Ans $E(\theta)$ at half power $= 0.707$

$0.707 = \cos\theta \cos 2\theta = \frac{1}{\sqrt{2}}$

$\cos 2\theta = \frac{1}{\sqrt{2}\cos\theta}$ $\Rightarrow 2\theta = \cos^{-1}\left[\frac{1}{\sqrt{2}\cos\theta'}\right]$

$\theta = \theta' = at\ 20.5$

(a) $\therefore HPBW = 2\theta = 41°$.

(b) FNBW

$0 = \cos\theta \cos 2\theta \Rightarrow \theta = \underline{45°}$

$\therefore FNBW = 90°$

Beam Area :

The beam area Ω_A is the solid angle through which all of the power radiated by the antenna would stream if $P(\theta,\phi)$ maintained its maximum value over Ω_A & zero elsewhere.

Thus power radiated = $P(\theta,\phi)\,\Omega_A$ watts

$$\Omega_A = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\theta=\pi} P_n(\theta,\phi)\, d\Omega \ \text{Sr}$$

→ The beam area (or) beam solid angle (or) Ω_A of an antenna is given by integral of the normalized power pattern over sphere.

$$\Omega_A = \int_0^{2\pi}\int_0^{\pi} P_n(\theta,\phi)\, d\Omega \qquad \text{where } d\Omega = \sin\theta\, d\theta\, d\phi.$$

→ The Beam area is approximated in terms of angles subtended by half power points of the main lobe in the two principal planes is B

$$\text{Beam area} = \Omega_A = \theta_{HP}\phi_{HP}.\ (\text{Sr})$$

θ_{HP}, ϕ_{HP} Half power beamwidth in the two principle planes

Note Normalized power = $P_n(\theta,\phi) = \dfrac{S(\theta,\phi)}{S(\theta,\phi)_{max}}$

(P) An Antenna has field pattern given by $E(\theta) = \cos^2\theta$. for $0\le\theta\le 90°$. Find beam area of this pattern.

$$\Omega_A = \int_0^{2\pi}\int_0^{\pi} \cos^4\theta \sin\theta\, d\theta\, d\phi$$
$$= \int_0^{2\pi} d\phi \int_0^{\pi} \cos^4\theta \sin\theta\, d\theta\, d\phi$$
$$= \int_0^{2\pi} d\phi \cdot -\left[\frac{\cos^5\theta}{5}\right]_0^{\pi} = -\frac{2\pi}{5}\left[\frac{-1}{5}\right] = \frac{2\pi}{5} = 1.26 \text{ Sr}$$

Approximate relation

$$\Omega_A \cong \phi_{HP}\,\theta_{HP}$$

$$\Omega_A = 66° \times 66° = 4356 \text{ Sq deg.}$$

$1\text{ Sr} = 3.2\times10^{3}$

$1\text{ Sr} = 3283.$ Sq

Beam area $= \Omega_A = 4356$ Sq degrees.

$= \dfrac{4356}{\ldots} = 1.33$ Sr

Beam efficiency

The Ratio of main beam area to total beam area is called beam efficiency.

Total beam area = main beam area + minor lobe area.

$$\therefore \varepsilon_M = \frac{\Omega_M}{\Omega_A} \quad \text{where } \Omega_M = \text{Main beam area}$$

Ω_A = Total beam area.
$= \Omega_M + \Omega_m$

The ratio of ~~minor~~ minor lobe area to the beam area is called stray factor

$$\varepsilon_m = \frac{\Omega_m}{\Omega_A} \quad \text{.. Stray factor.}$$

$$\boxed{\text{Note} : \therefore \varepsilon_M + \varepsilon_m = 1}$$

Radiation Intensity: The power radiated from an antenna per unit solid angle is called Radiation intensity. watts/steradians.

Directivity: The directivity of antenna is equal to ratio of max. power density $P(\theta,\phi)_{max}$ (watts/m²) to its avg. value over a sphere as observed in the far field of an antenna.

$$\therefore \text{Directivity } D = \frac{P(\theta,\phi)_{max}}{P(\theta,\phi)_{Avg}}$$

Directivity gives the capacity of antenna to concentrate the radiated power with the limited solid angle.

The Directivity is a Dimensionless ratio ≥ 1.

The Avg. power density over a sphere is given by.

$$P(\theta,\phi)_{Avg} = \frac{1}{4\pi}\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P(\theta,\phi)\sin\theta\, d\theta\, d\phi.$$

$$= \frac{1}{4\pi}\iint_{4\pi} P(\theta,\phi)\, d\Omega \quad \text{w/sr.}$$

$$\therefore \text{Directivity } D = \frac{P(\theta,\phi)_{max}}{\frac{1}{4\pi}\iint_{4\pi} P(\theta,\phi)\, d\Omega} = \frac{1}{\frac{1}{4\pi}\iint_{4\pi}\frac{P(\theta,\phi)\, d\Omega}{P(\theta,\phi)_{max}}}$$

$$\boxed{D = \frac{4\pi}{\iint_{4\pi} P_n(\theta,\phi)\, d\Omega} = \frac{4\pi}{\Omega_A}}$$ Directivity for beam Area

Note : the smaller beam area, the larger the directivity

Idealized Isotropic antenna has Lowest Directivity $D = 1$ ($\because \Omega_A = 4\pi$)

Gain : It is ratio of max. power density of the antenna under test to the max power density of the reference antenna.

$$\text{Gain } G = \frac{P_{max}(A.U.T)}{P_{max}(\text{ref antenna})} \times G(\text{ref. ant}).$$

Antenna efficiency factor : It is ratio of gain to Directivity

$$\boxed{K = \frac{G}{D}}$$

K = efficiency factor

range is $0 \leq K \leq 1$

→ If the half power beam width is known, then the directivity is

$$D = \frac{41253^\circ}{\theta_{HP}\phi_{HP}}$$

Antenna Aperture.

It is a ratio of power received at the antenna load terminal to the power density of incident wave.

$$\text{Aperture area (or) capture area} = \frac{\text{Power received}}{\text{Power density of incident wave}}$$

$$A_e = \frac{W}{P} \ (m^2)$$

A_e = aperture area
W = power received
P = power density of incident wave

$$\text{Aperture efficiency } \varepsilon_{ap} = \frac{A_e}{A_p}$$

A_e = effective aperture
A_p = physical aperture.

Aperture - beam area Relation

$$\lambda^2 = A_e \Omega_A$$

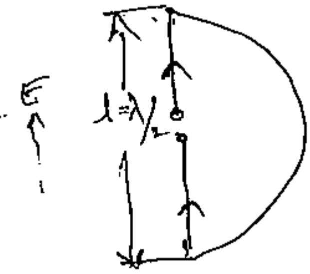
$$\text{Thus } D = \frac{4\pi}{\Omega_A} = \frac{4\pi}{\lambda^2} \cdot A_e$$

Effective height.

Effective height may be defined as the ratio of the induced voltage to the incident field or

$$h = \frac{V}{E} \text{ m.}$$

Consider, a vertical dipole of length $l = \lambda/2$, immersed in an incident field E, if the current distribution is sinusoidal with an avg value $2/\pi = 0.64$, so its effective height is $h = 0.64l$



Note: If the current distribution is uniform, then the effective height is 'l'.

- For an antenna of radiation resistance R_r, matched to its load, then the power ~~devel~~ delivered to the load is equal to,

$$P = \frac{1}{4}\frac{V^2}{R_r} = \frac{h^2E^2}{4R_r} \quad \text{— ①}$$

Interms of the effective aperture the same power is given by

$$A_e = \frac{W}{P} \Rightarrow W = P.$$
$$P = S$$

$$P = A_e S$$

$$P = \frac{E^2}{Z_0} A_e \quad \text{— ②}$$

$$\frac{h^2 \cancel{E^2}}{4R_r} = \frac{\cancel{E^2} A_e}{Z_0} \Rightarrow \boxed{h_e = 2\sqrt{\frac{A_e R_r}{Z_0}}}$$

$$\boxed{A_e = \frac{h^2 Z_0}{4R_r}}$$

Fields from oscillating dipole

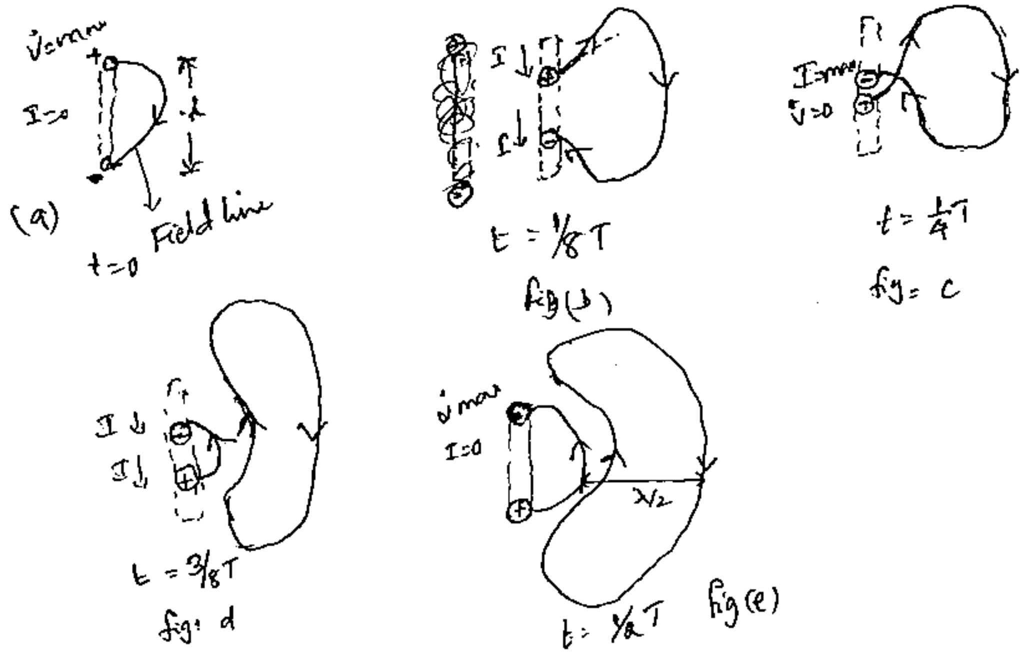
If a charge moving with uniform velocity along a straight conductor does not radiate.

If a charge moving back & forth in simple harmonic motion along the conductor is subject to acceleration (or deceleration) & radiates.

To illustrate radiation from a dipole antenna, let us consider a dipole, that has two ~~ch~~ equal charges of opposite sign oscillating up & down in harmonic motion with separation l.

At $t=0$, the charges are at the max. seperation & undergo max. acceleration $\dot{v}$ as they reverse direction. At this instant the current I is zero. shown in fig a.

At an $\frac{1}{8}$ period later, the charges are moving toward each other & at a $\frac{1}{4}$ period later they pass at mid point. As this happens the field lines detach & new ones of opposite sign are formed. At this time the equivalent current I is a maximum & charge acceleration is zero. As time progresses to a $\frac{1}{2}$ period, fields continue to move out, as shown in d & e.



(a) $t=0$

$t = 1/8\,T$ fig (b)

$t = \frac{1}{4}T$ fig: c

$t = 3/8\,T$ fig: d

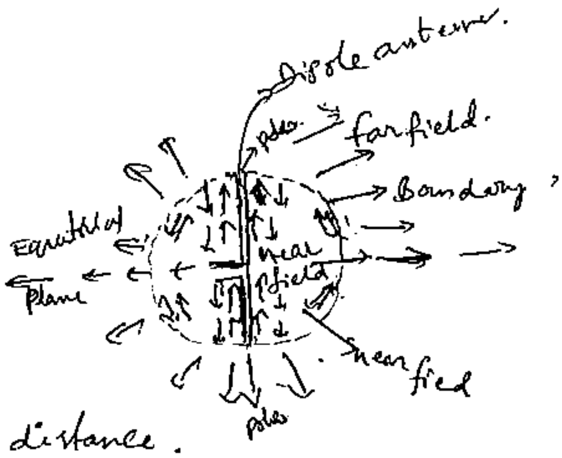
$t = 1/2\,T$ fig (e)

Antenna field Zones

The fields around an antenna may be divided into two principle regions one near the antenna called near field (or) Fresnel zone & one at large distance called the far field (or) Fraunhofer zone.

The boundary b/w the two may be arbitary taken to be at a radius $R = 2L^2/\lambda$ m where L = antenna length.
λ = wave length in m.

→ In the far (or) Fraunhofer region, the measurable field components are transverse to the radial direction from the antenna. & all power flow is directed ~~Rad~~ radially outward. In the farfield the shape of the field pattern is ~~indep~~ independent of the distance.



- In the near field (or) Fresnel region, the longitudinal component ~~of~~ of the electric field may be significant. & power flow ~~of~~ is not entirely radial. in the near field the shape of the field pattern depends, in general, on distance.

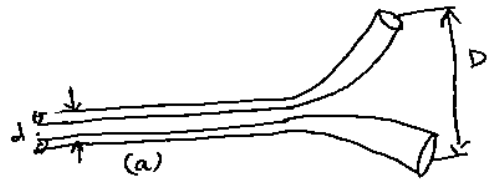
- The ~~R~~region near the ~~field~~ poles of the sphere act as a reflector. & the waves expanding perpendicular to the dipole in the equatorial region of the sphere. & partiall transparent in this region.

- For a $\lambda/2$ dipole antenna, the energy stored at one instant of time in the electric field, mainly near the ends of antenna (or) max. charge ~~R~~regions. while a $\frac{1}{2}$ period later, the energy is stored in the magnetic field mainly near the ~~centre~~ center of the antenna (or) max. current region.

Shape & Impedance Considerations:

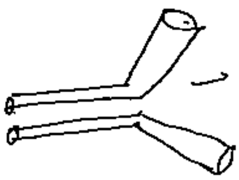
It is possible in many cases to deduce the qualitative behaviours of an antenna from its shape.

Starting with the opened-out two conductor transmission line, we find that if we extended far enough, a nearly constant impedance will be provided at the o/p.



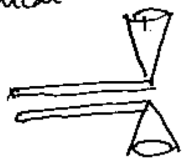
wide band width $= D/d$. $d \leq \lambda$, $D \geq \lambda$.

(b)



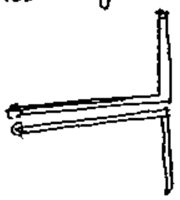
· Curved conductors are straightened into regular cones.

(c) The cones are aligned collinearly, forming a biconical antenna.



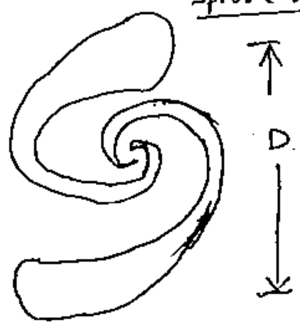
(b) and (c) are narrow B-W

(d) Cones degenerate into straight wires.



Narrow B.W

(e) Spiral antenna.



wide Band width

The antennas a & b are unidirectional, with beams to right, the another antennas c & d are omni directional. B.W of relatively constant impedance tends to decrease from a to d. The spiral antenna has wide BW.

Another set of antennas, antennas are fed from coaxial transmission lines.

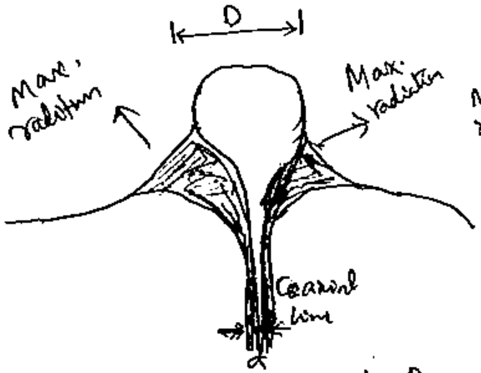
By ~~gradually~~ gradually tapering the inner & outer conductors (or) a coaxial transmission line, a very wide band antenna with an appearance of a volcanic crater & puff of smoke is obtained. shown in fig (a).

The Volcano form is modified into a double cone shown in fig(b). and another one is two wide angle cones. All of these antennas are omni directional in a plane ⊥r to their axes. & all have ~~wide~~ wide B.W

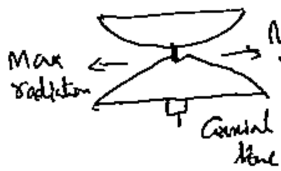
Another one is Biconical antenna, with a full cone angle of 120° has an omnidirectional ~~pattern~~ pattern & nearly constant 50Ω i/p impedance. shown in fig(C).

Increasing the Lower Cone angle to 180° while reducing the Upper Cone angle results ~~to the~~ antenna shown in fig(d).

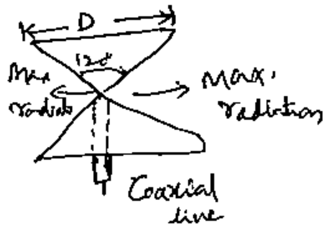
collapsing the upper cone into a thin stub, we will get the another antenna shown in fig(e).



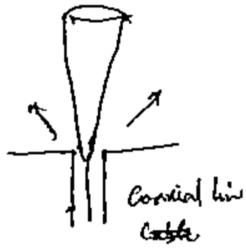
fig(a) Wide B.W



(b)

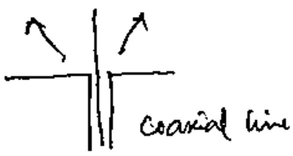


(C)



(d)

Narrowest B.W.



(e)

Narrowest B.W

Antenna temperature :

The brightness temperature of an extended source of radiation measured in a particular direction is the temperature of a black body which yields brightness equal to that of source under consideration.

The brightness B is defined as the power received per unit area of aperture per cycle of B.W per unit solid angle.

At radio & radar freq., the brightness temp is

$$\boxed{B = 2KT_B/\lambda^2}$$

K = Boltzmann Const. 1.68×10^{-23} J/K

λ = Wave length

- Mean brightness temperature in the field of antenna pattern is called the antenna temperature.

Front to back Ratio :

The ratio of energy radiated in the front & back directions through the main & back loses is termed as front to back ratio.

~~properties~~ Antenna theorems are as under the properties :

Equality of directional pattern : The directional pattern of a receiving antenna is identical with the directional pattern as a transmitting antenna.

Equality of transmitting & receiving antenna impedance : The impedance of an isolated antenna when used for receiving is the same as when used for transmitting

Equality of effective length : The effective length of an antenna for receiving is equal to its effective length as a transmitting antenna.

Basic Maxwell Equations

The relevant equations involving electric field intensity E (V/m), electric flux density D (C/m²), magnetic flux density B (Web/m²), magnetic flux intensity H (A/m), current density J (A/m²) & charge density ρ (C/m³) are given below. A is magnetic vector potential.

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$ — Ampere's law.

$J = \sigma E$

σ : Conductivity

$$\nabla \times E = -\frac{\partial B}{\partial t}$$ — Faraday's law

$$\nabla \cdot D = \rho$$ — Gauss law (E field)

$$\nabla \cdot B = 0$$ — Gauss law (H-field).

$$D = \epsilon E \quad , \quad B = \mu H.$$

Retarded (Time Varying) potentials

$$E = -\nabla V$$

$$\nabla^2 V = -\rho/\epsilon \quad \& \quad \nabla^2 V = 0 \quad \text{if } \rho = 0$$

$$B = \nabla \times A$$

$$\nabla^2 A = -\mu J \quad \& \quad \nabla^2 A = 0 \quad \text{for } J = 0$$

$$\boxed{\nabla \times E = \nabla \times (-\nabla V) = 0.}$$ ($\because$ curl of a gradient is zero)

Let $E = -\nabla V + N$.

$$\nabla \times E = \nabla \times (-\nabla V) + \nabla \times N$$

$$= 0 + \nabla \times N$$

$$-\frac{\partial B}{\partial t} = -\frac{\partial}{\partial t}(\nabla \times A) = \nabla \times N$$

Thus $$\nabla \times N = \frac{-\partial (\nabla \times A)}{\partial t}$$

$$= -\nabla \times \frac{\partial A}{\partial t}$$

$$= \nabla \times -\partial A/\partial t$$

$$\therefore N = -\partial A/\partial t$$

$$\therefore \boxed{E = -\nabla V - \frac{\partial A}{\partial t}}$$

$\frac{\partial A}{\partial t}$ = time rate of change of vector magnetic potential.

(2) $\nabla\cdot D = \nabla\cdot(\varepsilon E) = \varepsilon\,\nabla\cdot E$

$$= \varepsilon\nabla\cdot\left[-\nabla V - \partial A/\partial t\right]$$

$$\rho = \varepsilon\left[-\nabla\cdot\nabla V - \partial/\partial t(\nabla\cdot A)\right] = \rho$$

from the above relation $\underline{\nabla^2 V + \partial/\partial t(\nabla\cdot A) = -\rho/\varepsilon}$

$\nabla^2 V = -\rho/\varepsilon$ — for static conditions

$\nabla^2 V = -\rho/\varepsilon - \partial/\partial t(\nabla\cdot A)$ — for time varying conditions.

(3) $\nabla\times H = J + \dfrac{\partial D}{\partial t}$

$B = \mu H$ (or) $H = B/\mu$

LHS $(\nabla\times B)/\mu = \dfrac{(\nabla\times\nabla\times A)}{\mu} = \left[\nabla(\nabla\cdot A) - \nabla^2 A\right]/\mu.$

RHS : $J + \varepsilon\,\partial E/\partial t = J + \varepsilon\,\partial(-\nabla V - \partial A/\partial t)/\partial t$

$$= J + \varepsilon\left(-\nabla\left(\frac{\partial V}{\partial t}\right) - \frac{\partial^2 A}{\partial t^2}\right)$$

$$= J - \varepsilon\left[\nabla\left(\frac{\partial V}{\partial t}\right) + \frac{\partial^2 A}{\partial t^2}\right]$$

$$\therefore\ \nabla(\nabla\cdot A) - \nabla^2 A = \mu J - \mu\varepsilon\left(\nabla\left(\frac{\partial V}{\partial t}\right) + \frac{\partial^2 A}{\partial t^2}\right]$$

As per the statement of Helmholtz Theorem, "A vector field is completely defined only when both its curl & divergence are known".
There are some conditions which specify the divergence of A. These are Lorentz Gauge Condition & Coulombs' gauge condition.

$\nabla\cdot A = -\mu\varepsilon\dfrac{\partial V}{\partial t}$ → Lorentz Condition

$\nabla\cdot A = 0$ → Coulombs Condition.

Using Lorentz gauge condition.

$$\nabla^2 V = -\rho/\varepsilon - \partial/\partial t\left(\mu\varepsilon\frac{\partial V}{\partial t}\right)$$

$$= -\rho/\varepsilon - \mu\varepsilon\frac{\partial^2 V}{\partial t^2}$$

$Ve^{j\cdot}$

$$\nabla^2 A = -\mu J + \mu\varepsilon\left(\frac{\partial^2 A}{\partial t^2}\right).$$

For sinusoidal time variation characterized by $e^{j\omega t}$

$V = V_0 e^{j\omega t}$ & $A = A_0 e^{j\omega t}$

$\nabla^2 V = -\rho/\varepsilon + \omega^2\mu\varepsilon V$ & $\nabla^2 A = -\mu J + \mu\varepsilon\,\partial^2 A$

Resolution :

The Resolution of an antenna may be defined as equal to the half the Beam width b/w the first nulls (FNBW)/2.

Half the Beam width b/w first nulls is approximately equal to the half power Beam width (HPBW)

$$\therefore \frac{FNBW}{2} = HPBW.$$

$$\text{Thus } \Omega_A = \left(\frac{FNBW}{2}\right)_\theta \left(\frac{FNBW}{2}\right)_\phi.$$

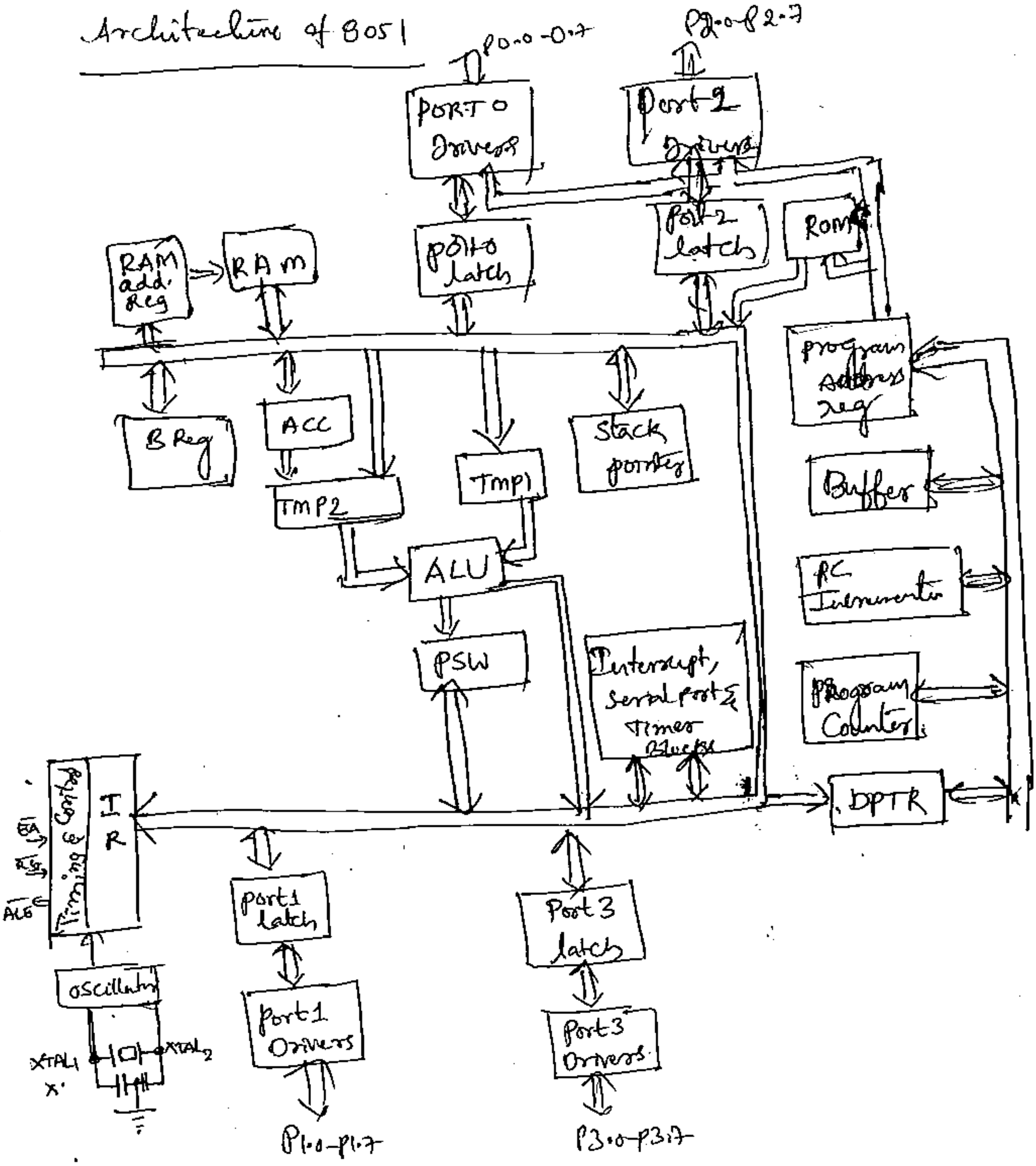
The Number 'N' of radio transmitters (or) point sources of radiation ~~[illegible]~~ distributed uniformly over the sky which an antenna can resolve is given by

$$N = \frac{4\pi}{\Omega_A} \qquad \Omega_A \text{ : beam area}$$

However $D = \frac{4\pi}{\Omega_A}$

$$\therefore \boxed{N = D}$$

Architecture of 8051



Accumulator (ACC): The ACC (or) 'A' acts as an operand register. This is either be implicit or specified in the instruction. The ACC register address is alloted in the on-chip special function register bank.

B Register: It is used to store one of the operands for multiply & Divide ~~operat~~ instructions.

Program status Word: This set of flags contains the status information & is considered as one of the SFR.

Stack pointer: This register contains 8 bit stack top address. The stack may be defined anywhere in the on-chip 128 bytes RAM. After Reset, the SP register is initialized to 07.

DPTR: This 16-bit Register contains a higher byte (DPH) & the lower byte (DPL) of a 16-bit ~~xxx~~ external data RAM address. It is accessed as a 16-bit register or two 8-bit registers as specified above.

Port 0 to 3 latches & Drivers: These four latches & driver pairs are ~~alto~~ alloted to each of the four on-chip I/O ports. These latches have been allotted address in the SFR banks. Using allotted address user can communicate with these ports. These are P0, P1, P2, P3.

Timer Register: ~~these~~ ~~two~~ There are two timer registers T0, T1. These two are 16-bit registers. These can accessed as two 8 bit registers.

Control registers: The special function registers IP, IE, TMOD, TCON, SCON, & PCON contain control & status information for the interrupts, timers/counters & serial port.

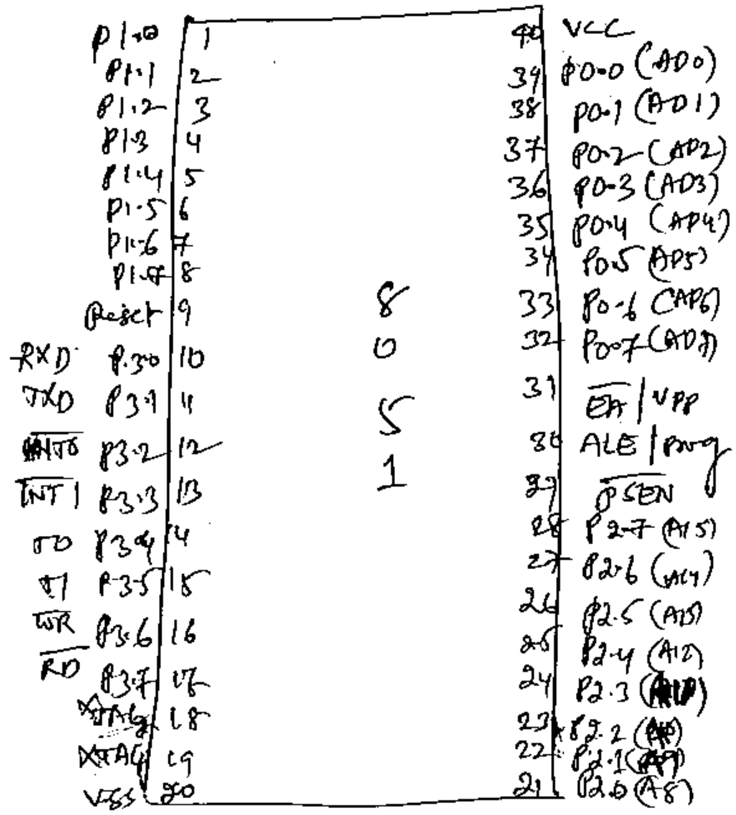
Timing & control unit: This unit derives all the necessary timing & control signals required for the internal operation of the circuit. It also derives control signals required for controlling the external system bus.

Oscillator : This circuit generates the basic ~~clo~~ timing ~~clo~~ clock signal for the operation of the circuit using Crystal oscillator

Instruction register : This register decodes the opcode of an instruction to be executed & gives the information to the timing & control unit to generate the necessary signals for the execution of the instruction.

ALU : The arithmatic and logic unit performs 8 bit arithmatic and logical operations over the operands held by the temp. registers TMP1 & TMP2. Users can not access these ~~temp~~ temporary registers.

pin diagram of 8051



Register set of 8051

Registers of 8051.

A, B, PSW, P0, P1, P2, P3, IP, IE, TCON, SCON,

SP, DPH, DPL, TMOD, TH0, TL0, TH1, TL1, SBUF, PCON.

– And also 4 register banks for general purpose registers

Bank 0 → $R_0 - R_7$
Bank 1 $R_0 - R_7$
Bank 2 $R_0 - R_7$
Bank 3 $R_0 - R_7$

– General purpose reg. are stored in the onchip RAM. Starting 32 bytes are reserved for this (0000 to 001FH).

– Addresses of the remaining registers are available in the Special Function Bank.

PSW : (program status word.)

CY	AC	F0	RS1	RS0	OV	—	P

RS1	RS0	Reg. Bank	Address
0	0	Bank0	00 – 07
0	1	Bank 1	08 – 0FH
1	0	Bank2	10H – 17H
1	1	Bank3	18H – 1FH

OV – overflow flag
P – parity flag

TMOD Format

Gate	C/T	M1	M0	Gate	C/T	M1	M0
Timer 1				Timer 0.			

Gate : When TRx (in TCON) is set & Gate = 1, Timer/Counter$_x$ will run only while INTx pin is high, when Gate=0, Timer/Counter$_x$ will run only while TRx = 1.

C/T → Timer/Counter selector. It is zero select the timer operation other wise Counter.

M1 M0	operation
0 0	Mode 0, 13 bit Timer
0 1	Mode 1, 16 bit Timer/Counter
1 0	Mode 2 8 bit auto Reload Timer
1 1	Mode 3. (Timer 0) TL0 is an 8 bit Timer/Counter Controlled by Timer 0 Control bits, TH0 is an 8 bit timer & Controlled by Timer 1 Control bits,
1 1	Mode 3 - (Timer 1) Timer/Counter 1 stopped.

TCON Format

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

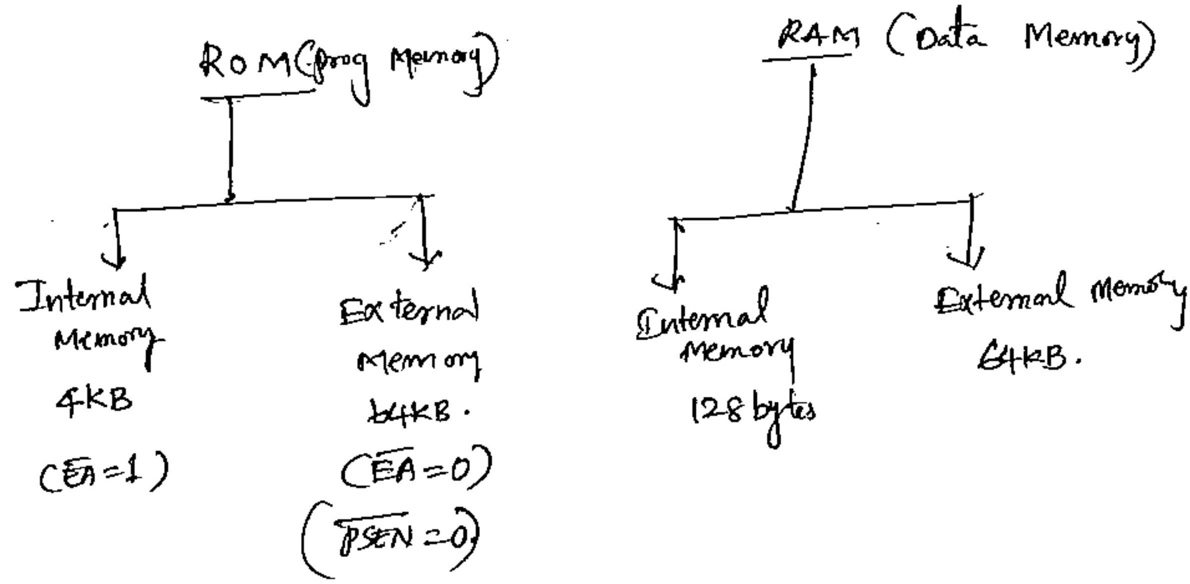
- TF1 → Timer 1 overflow flag
- TR1 → Timer 1 run Control bit
- TF0 → Timer 0 overflow flag
- TR0 → Timer 1 Run bit
- IE1 → External Interrupt 1 flag
- IT1 → Interrupt 1 type Control bit
- IE0 → Int 0
- IT0 → Int type 0 bit.

TF1 → this is set by H/w when Timer/Counter 1 overflows & is cleared by H/w as processor vectors to the interrupt service routine.

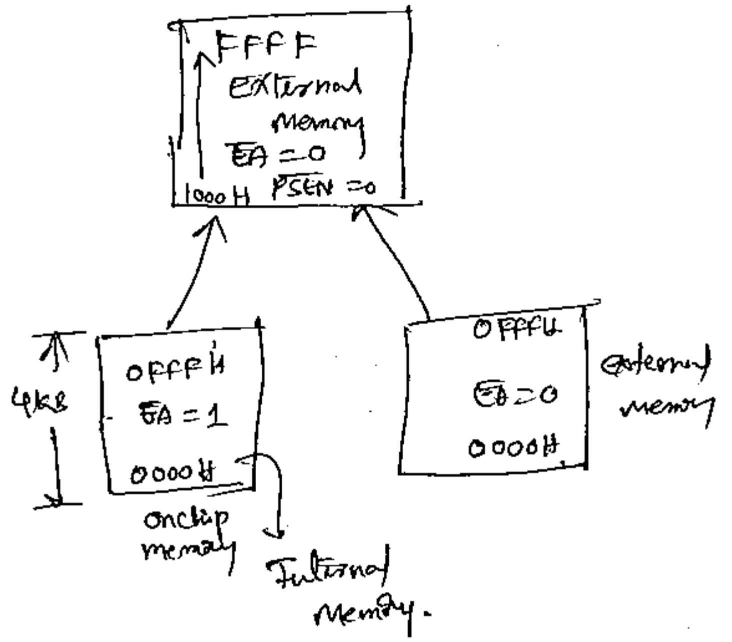
TR1 → This is set/cleared by S/w to run Timer/Counter 1 ON/OFF.

IE1 → This is set by H/w when external interrupt edge is detected & is cleared by H/w when the interrupt is processed.

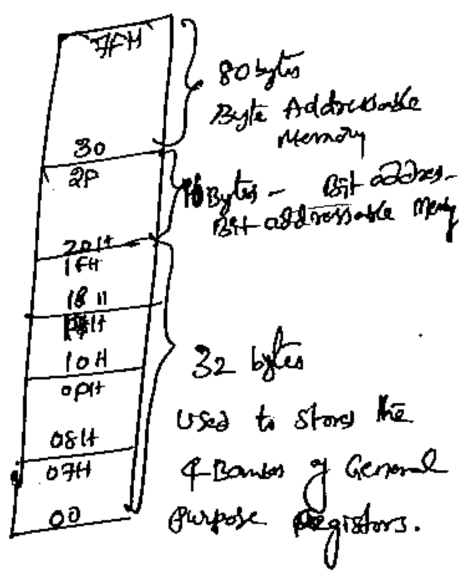
Memory organization



ROM



RAM (128 bytes)



Internal RAM

1. First 32 bytes from address 00H to 1FH are reserved for general purpose registers.
   4 banks of 32 general purpose registers is bit addressable
2. Next 16 bytes that is form 20H to 2F is bit addressable memory. An addressable bit may be specified by its bit address of 00H to 7FH. For Ex., the bit address 4FH is also a bit of 7 of the byte address 29 H. Addressable bits are useful when the prog. need only remembers a binary event. (Switch ON (or) light OFF. etc).

Interrupts 8051

8051 five sources of interrupts.

Interrupt source	priority
IE0 – External (INT0)	Highest
TF0 (Timer 0)	
IE1 (External INT 1)	
TF1 (Timer 1)	
RI = TI (Serial port)	Lowest

Interrupt enable register

EA	–	ET2	ES	ET1	EX1	ET0	EX0

→ If EA = 0, no interrupt will be acknowledged.
EA = 1, each interrupt source is enabled or disabled by setting (or) clearing its enable bit.

→ ET2. This enables Timer2 overflow [8052)
– ES – This enables (or) disables the serial port interrupt.
· ET1 – This enables (or) disables Timer 1 overflow interrupt.

:

Interrupt priority Register :

–	–	PT2	PS	PT1	PX1	PT0	PX0

PT2 – This defines the Timer 2 interrupt priority level.

PS – This defines the serial port interrupt priority level.

PT1/PT0 → This defines the Timer1 / Timer0 interrupt priority level

PX1 / PX0 – This defines the $\overline{INT1}$ / $\overline{INT0}$ priority level.

Addressing Modes:

(1) Direct Addressing mode
(2) Indirect addressing mode
(3) Register Addressing mode
(4) Register specific (Register implicit addressing mode)
(5) Immediate addressing mode.
(6) Indexed addressing mode.

(1) Direct addressing Mode:

In this addressing mode, the 8 bit address of an operand are specified ~~[illegible]~~ is specified directly in the instruction

Ex Mov Ro, 89 H.

(2) Indirect addressing mode:

In this mode, the 8 bit address of an operand is stored in register. & the register, instead of 8 bit address, is specified in the instruction.

ADD A, @Ro.

(3) Register Addressing mode: Specify the operand my means of any register.

Ex: Mov A, Ro.
Mov A, R1.

(4) Immediate Addressing mode:

Specify the data directly in the instruction.

Ex Mov A, # 50H.

(5) Instruction set

External data Move Instruction :

Movx A, @Rp , copy of the contents of the external address in Rp to A

Movx @DPTR, A Copy data A to the 16 bit external address in DPTR.

Movx @R0, A ; copy data from A to the 8 bit address in R0.

Code memory Read only data moves

MovC A, @A+DPTR ; Copy the code byte from address found by adding of A & DPTR to A.

MovC A, @A+PC ; Copy the code byte from address found by adding of A and the PC to A.

Push & pop instructions:-

push add ; increment SP ; copy the data in address to the internal RAM address contained in SP.

POP add ; copy the data from the internal RAM address contained in SP to add ; decrement the SP.

Data exchanges:

XCH A, Rn ; Exchange the data bytes b/w reg Rn and A.

XCH A, add ; Exchange the data bytes b/w add And A.

XCHD A, @Rp ; Exchange the lower nibble in A & the add. in Rp.

Byte level Logical Operations :

ANL A, #n ; AND each bit of A with the same bit of immediate number n ; & put the result in A.

ORL A, #n ; OR each bit of A with the same bit of immediate number n ; & put the result in A.

XRL A, #n ; XOR each bit of A with the same bit of immediate number n ; & put the result in A.

CLR A ; clear each bit of the A register to 0.
CPL A ; complement each bit of A ; every 1 becomes a 0 ; & each 0 becomes a 1.

Bit level logical operations.

ANL C,b ; AND C and the addressed bit ; put the result in C.

ANL C,/b AND C and the complement of the addressed bit. & put the result in C & the addressed bit is not altered.

ORL C,b OR C and the addressed bit ; put the result in C.

CLR b Clear the addressed bit is 0.

MOV C,b : copy the addressed bit to the C flag.

SETB C Set the C flag to 1.

SETB b Set the addressed bit to 1.

Rotate and swap operation Instructions.

RL A ; Rotate A register one bit position to the left.

RLC A Rotate the A register & the carry flag as ninth bit, one bit position to the left.

RR A ; Rotate A register one bit position to the right.

RRC A ; Rotate A register & Carry flag as ninth bit, one bit position to right ie bit A0 to C, C to A7, A7 to A6, A6 to A5 etc.

SWAP A ; Interchange the nibble of register A. ie put the higher nibble in the low nibble position & the lower nibble in the high nibble position.

Arithmatic Instructions.

ADD A, #n ; Add A & the immediate number n; put the sum in A.

SUBB A, #n ; Subtract immediate value from A and the Result is stored into A.

MUL AB ; Multiply A by B. put the low-order byte of the result in A & put the high order byte in B.

DIV AB ; Divide by A by B ; put the integer part Quotient into A & integer part of Remainder into B.

INC A ; Add 1 to the A reg.

DEC A subtract '1' to the A reg.

DA A Adjust the sum of two packed BCD numbers found in A register, leave the adjusted number in A.

Jump Instructions

JC radd ; Jump to relative address if the carry is set to 1.

JB b,radd ; Jump to relative address if the addressable bit is set to 1.

JNB b,radd ; " " if the addressable bit is resets.

JBC b,radd ; " " if the addressable bit is set & clear the addressable bit to 0.

CJNE A,add, radd ; compare the contents of A reg with the contents of the direct address, if they are not equal, then jump to the relative address. Set the carry flag 1 if A is less than the contents of the direct address.

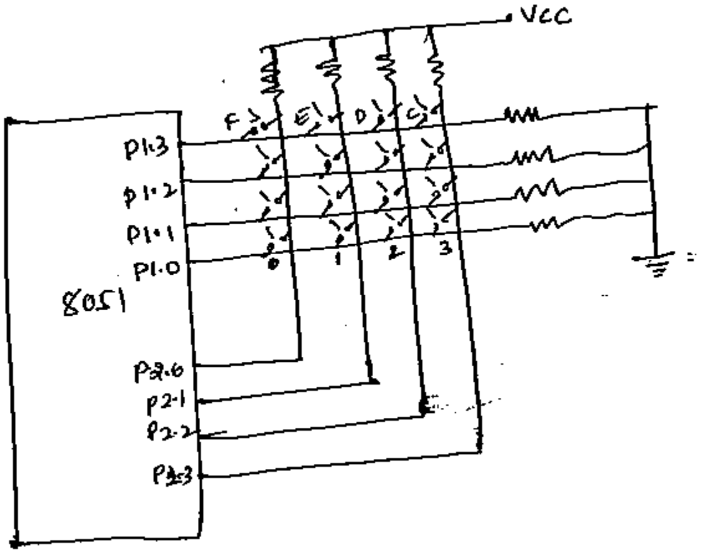
CJNE A, #n,radd.

DJNZ Rn, add ; Decrement the reg. Rn by 1 & Jump to the relative address if the result is not zero. No flags are effected.

Differences between Microprocessors & Microcontrollers

Micro processors	Micro Controllers
① Micro processers does not have On chip memory, timers, I/O ports.	① Micro Controllers has on chip memory, Timers & IO ports.
② It has one (or) two bit handling Instructions	② It has more number of bit handling Instructions.
③ Access time for memory & IO is more.	③ Access time is less.
④ It requires more Hardware	④ It requires less H/w.
⑤ More Flexible	⑤ ~~More~~ Less Flexible.
⑥ Less Number of ~~bit~~ pins are multiplexed.	⑥ More No. of Pins are Multiplexed.

Key Board Enterfacing. With 8051



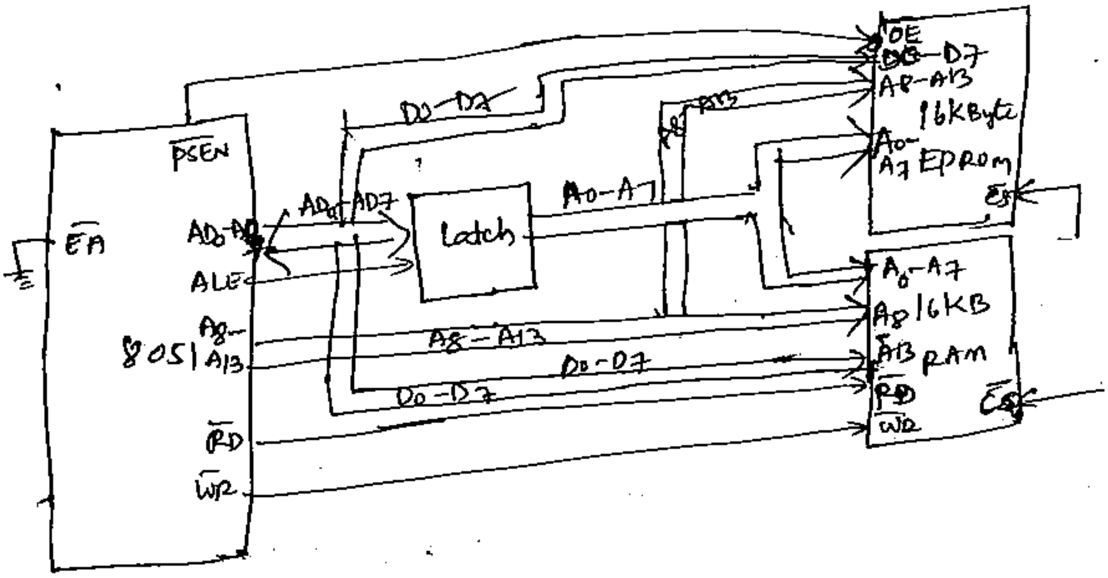

```
      Mov P2, # FFH
Go:   Mov P1, #00H
      MOV A, P2
      ANL A, #0FH
      CJNE A, #0FH, Go
      ACALL Delay
Go2:  Mov P1, #00H
      MOV A, P2
      ANL A, #0FH
      CJNE A, #0FH Go1
      SJMP Go2
Go1:  ACALL Delay
      Mov P1, # 1111 1110B (FEH)
      mov A, P2
      ANL A, #0FH
      CJNE A, #0FH, ROW-0
      MOV P1, # 1111 1101 B
      mov A, P2
      ANL A, #0F H
      CJNE A, #0FH, ROW-1
      mov P1, # 1111 1011 B
      MOV A, P2
      ANL A, #0FH
```

```
      MOV P1, # 1111 0111 B
      mov A, P2
      ANL A, #0FH
      CJNE A, #0FH, Row-3
      LJMP Go2.
Row-0: MOV DPTR, #Kcode0
      SJMP FIND
Row-1: Mov DPTR, # Kcode1
      SJMP Find
Row-2: MOV DPTR, # Kcode2
      SJMP Find
Row-3: MOV DPTR, # Kcode3
      SJMP Find.
Find: RRC A
      JNC Bit
      INC DPTR
      SJMP Find
Bit:  CLR A
      Movc A, @A + DPTR
      MOV P0, A
      SJMP Go

ORG 0000H
Kcode0: DB '0', '1', '2', '3'
Kcode1: DB '4', '5', '6', '7'
Kcode2: DB '8', '9', 'A', 'B'
Kcode3: DB 'C', 'D', 'E', 'F'
END.

Delay: Mov R1, # FFH
Here:  DJNZ R1, Here
```

Memory Interfacing of 8051



LCD interfacing

If RS = 0 ; Command code register is selected, allowing the User to send a Command such as clear display, cursor at home.

RS = 1 , data reg. is selected, allowing the User to send data to be displayed on the LCD.

R/W = 0 → write the information to the LCD.

R/W = 1 → Read the information from it.

E = Enable the LCD.

D_0-D_7 → Used to send the information to the LCD (or) read the contents of the LCD's internal reg.

LCD Command Codes

01 → clear display screen.

02 → Return home.

04 — shift Cursor to left

06 — Shift Cursor to Right.

05 — Shift display right

07 — shift display left

08 — Display off, Cursor off

0A — Display off, Cursor on

0C — Display on, Cursor off

0E - Display on, Cursor blinking

0F — Display ON, Cursor blinking

10 — Shift Cursor position to left

14 — Shift Cursor position to Rt

18 — shift entire display to left

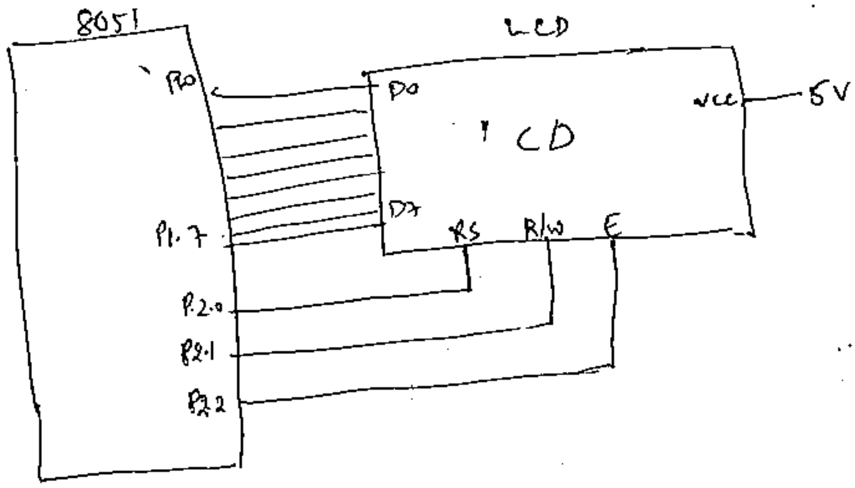
1C - shift entire display to Rt

80 — Force cursor to beginning 1st line

C0 — Force " 2nd line

38 — 2 lines & 5x7 matrix.

Interfacing diagram



```
ORG 0000H
MOV A, #38H      ; Initialize LCD 2 lines, 5x7 matrix.
ACALL COMMAND    ; Call Command Subroutine.
ACall delay.
MOV A, #0EH;     Display ON, Cursor ON.
ACALL Command
ACALL Delay.
MOV A, #01       ; Clear LCD
ACALL Command
ACALL Delay
MOV A, #06H      ; Shift Cursor right.
ACALL Command
ACALL Delay.
MOV A, #80H      ; Cursor at line 1, pos 0
ACALL Command
ACALL Delay.
MOV A, #'H',     ; Display letter H.
ACALL Display
ACALL Delay
MOV A, #'E' ;
ACALL Display
ACALL Delay.

again: SJMP again

Command:  MOV P1, A ;   Copy reg A to Port A
          CLR P2.0  ;   RS=0; for Command.
          CLR P2.1      R/W=0, for write
          SETB P2.2 ,   E=1 for high pulse
          ACALL delay
          CLR P2.2 .    E=0, for H to L pulse.
          RET.

Display:  MOV P1, A ;   Copy reg A to port A
          SETB P2.0 ;   RS=1, for data
          CLR P2.1.     R/W=0 for write
          SETB P2.2     E=1
          ACALL Delay
          CLR P2.2      E=0 for H to L pulse.
          RET.

Delay: MOV R3,#50
here1: MOV R4,#200
here:  DJNZ R4, here
       DJNZ R3, here1
```

Serial Data communication

SCON is used to controls the data Communication & SBUF is used to hold the data, PCON Controls the data rates.

The serial data flags in SCON, TI & RI are set when ever a data byte is transmitted (TI) or received (RI).

Data transmission:

Transmission of serial data bits begins any time data is written to SBUF. TI is set to 1 when the data is transmitted & signifies that SBUF is empty. & that another data byte can be sent.

Data Reception:

Reception of serial data will begin if the receive enable bit (REN) bit in SCON is set to 1 for all modes. In addition, for mode 0 only RI must be cleared to 0. Receiver Interrupt flag (RI) is set after data has been received in all modes.

SCON Register format

SM0	SM1	SM2	REN	TB8	RB8	TI	RI

SM0	SM1	Mode	Description	Baud Rate
0	0	0	Shift register	f oscillator/12
0	1	1	8-bit UART	variable
1	0	2	9 bit UART	f/32 (or) f/64
1	1	3	9 bit UART	Variable.

SM2 → This enables the multiprocessor communication feature in mode 2 & 3.

In mode 2 (or) 3, if SM2 = 1 & then RI will not be activated, if the received 9th bit (RB8) is 0.

In mode 1, if SM2 = 1, Then RI will not be activated, if a valid stop bit ~~was~~ not ~~received~~ received.

In mode 0, SM2 is should be 0.

REN - 1 : Receiving Enabled
= 0 ; Receiving disabled.

TB8 - This selects 9^{th} bit that will be transmitted in modes 2 & 3.

RB8 - This is 9^{th} data bit that was received in mode 2 & 3.

TI → Transmit Interrupt flag - this is set by H/W at the end of the 8^{th} bit time in mode 0 (or) at the begining of the stop bit in other modes. This is must be cleared by S/W.

RI - Receive Interrupt flag - This is set by H/W at the end of the 8^{th} bit time in mode 0 (or) Half way through the stop bit time in other modes excepting the case where SM2 is set. This must be cleared by S/W.

PCON

SMOD	—	—	—	GF1	GF0	PD	IDL

SMOD = 1 = Double baud rate is selected for timer 1 in mode 1, 2, 3
SMOD = 0 = Same Baud rate. of timer 1.

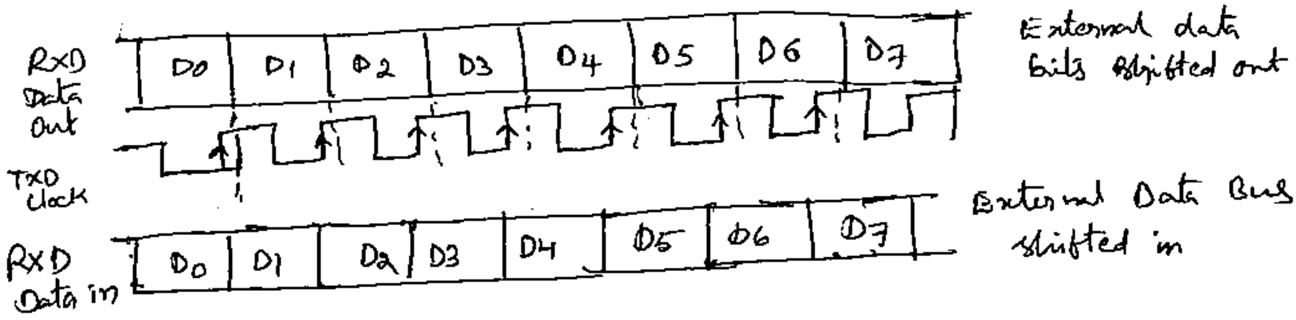
GF1 & GF0 → General purpose user defined flags.
PD = 1 → power down mode is selected
IDL = 1 → Idle mode is selected.

Serial Data transmission modes

Mode 0 : Shift Register mode :

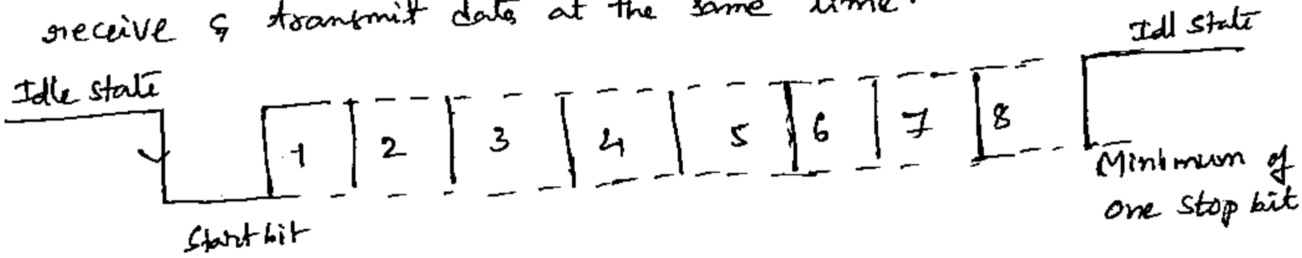
Setting bits SM0, SM1 in SCON is 0 0 Configures SBUF to receive or transmit 8 bits using Pin RXD for both functions. Pin TXD is connected to the internal shift frequency pulse source to supply the pulses to external circuits.

When transmitting, data is shifted out of RXD, the data changes on the falling edge (or) one clock pulse after the raising edge of the o/p TXD shift clock.



Mode 1 (Standard UART)

SBUF becomes 10 bit full duplex receiver / Transmitter that may receive & transmit data at the same time.



Mode 1 Baud rates:

Timer 1 is used in timer mode 2, then Baud rate

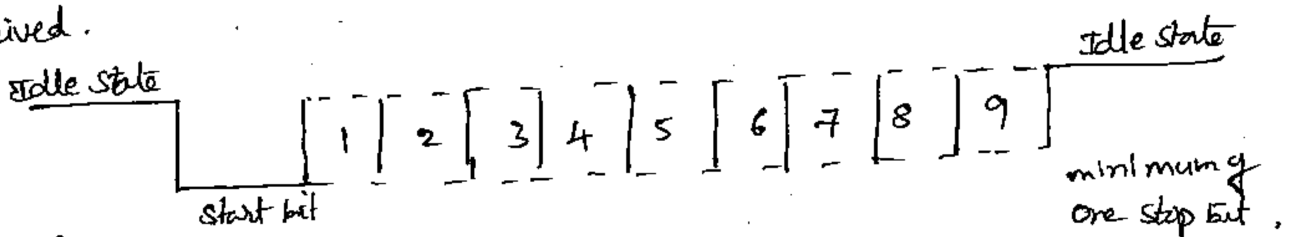
$$f_{Baud} = \frac{2^{SMOD}}{32d} \times \frac{\text{oscillator frequency}}{12d\,[256d - (TH1)]}$$

If Timer 1 is not run in timer mode 2, then Baud rate is

$$f_{Baud} = \frac{2^{SMOD}}{32d} \times (\text{Timer 1 overflow frequency}).$$

Serial Data Mode 2 : Multiprocessor mode.

Similar to mode 1, except 11 bits are transmitted ; a start bit, 9 data bits, one stop bit. The 9^{th} data bit is copied from bit TB8 in SCON during transmit & stored in bit RB8 of SCON when data is received.



$$f_{Baud} = \frac{2^{SMOD}}{} \times \text{oscillator frequency}.$$

MODE 3 :

Mode 3 is identical to mode 2, except that the baud rate is determined exactly as in mode 1 using timer 1.

Timers & Counters :

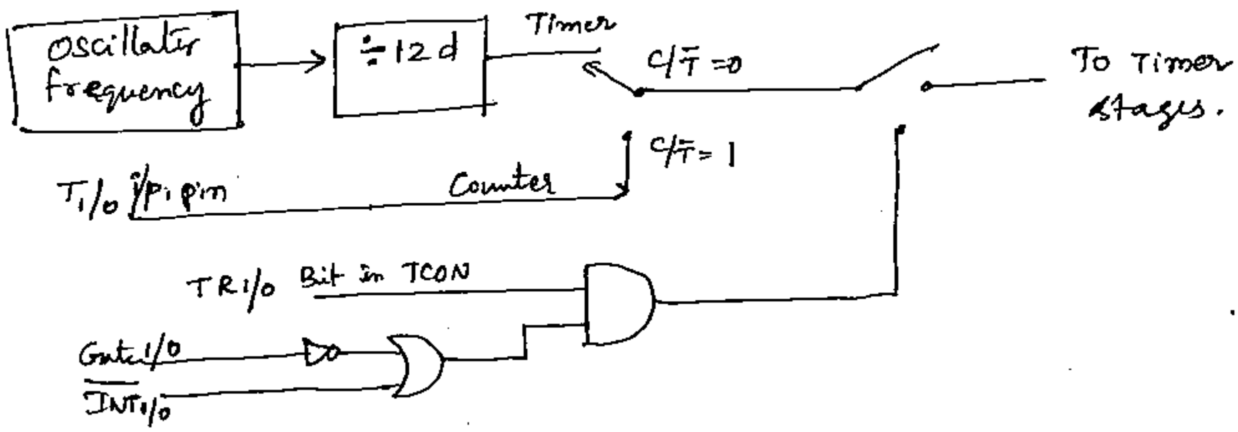
~~Explain~~ ~~TCON~~

Counter may be programmed to count the internal clock pulses as a timer (or) programmed to count external pulses as a counter.

When used as a timer, clock pulses are sourced from the oscillator through the divide by 12d circuit, when used as a counter pin T_0 supplies pulses to counter 0 & pin T_1 supplies pulses to counter 1.

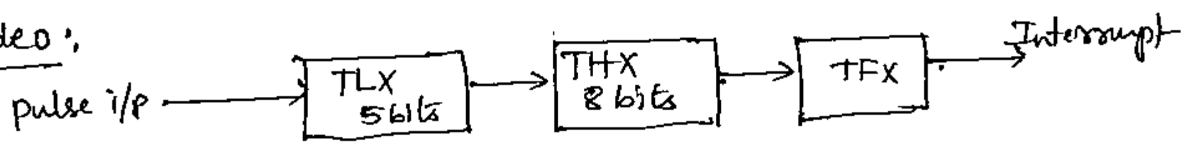
Then explain TCON & TMOD registers. These are ~~also~~ explained in the previous topic.

Logic diagram of Timer / Counter



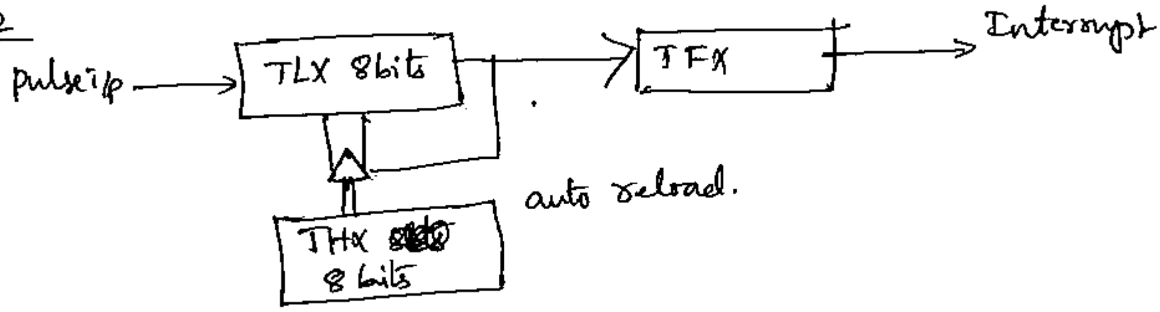
Timer Modes

Mode 0 :

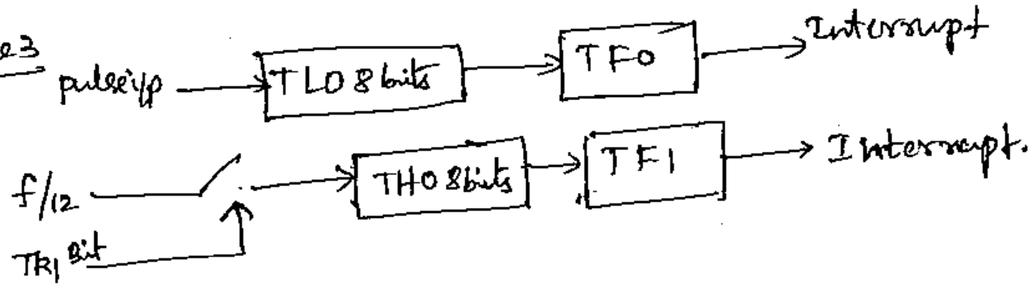


Mode 1

Mode 2



Mode 3



IO ports :

IO ports

port 0.0 to ~~port~~ 0.7 (P0.0 to P0.7)

Port 0 is an 8 bit bidirectional bit addressable IO port. This has been alloted an address in the SFR address range. port 0 act as multiplexed address / data lines during external memory access.

Port 1 (P1.0 to P1.7) :

Port 1 act as a 8-bit bidirectional bit addressable IO port. This has been allotted an address in SFR address range.

port 2 (P2.0 to P2.7) :

Port 2 acts a 8 bit bidirectional bit addressable IO port. During the external memory access, port 2 emits higher eight bits of address lines which are valid if ALE=1, $\overline{EA}$=0.

ports (P3.0 to P3.7) : Port 3 is an 8 bit bidirectional bit addressable IO port, The port 3 pins also serve the alternate functions.

P3.0 → Acts as Serial i/p data pin (RXD)
P3.1 → Acts as Serial o/p data pin (TXD)
P3.2 → Acts as External interrupt Pin 0 ($\overline{INT_0}$)
P3.3 → Acts as " " " 1 ($\overline{INT_1}$)
P3.4 → Acts as External i/p to timer 0 (T_0)

P3.6 - Acts as write control signal for external data memory ($\overline{WR}$)

P3.7 → Acts as ~~Read~~ Read control signal for external data ~~mem~~ memory ($\overline{RD}$).

(1) Assigning interrupt priorities.

```
MOV IE, #8CH  ; Enable EX1 & ET1
SETB PT1      ; Timer1 interrupt has high priority.
```

(2) Initializing Timer1 in mode 1

```
MOV TMOD, #10H  ; Timer1 mode 1.
SETB TR1        ; Start Timer1.
CLR TR1         ; Stop timer1
$: SJMP $.
```

(3) Program to Initialize timer 1 in mode 1

```
~~MOV SP, #54~~
MOV TMOD, # 00010000B ; Timer1 in mode 1
SETB ET1  ; Enable the timer 1 interrupt
SETB TR1  ; Start timer1
SETB EA   ; Enable all interrupt Access.
$: SJMP $
```

Note: The above prog. will Start timer1 and when it overflows, timer1 interrupt is generated, which will cause the PC to Jump to vector location 001BH.

(4) Initializing timer0 in mode 2.

```
MOV TMOD, # 0000 0010 B.
MOV TH0, #33H
MOV TL0, #33H.
SETB TR0
$: SJMP $
```

(5) prog. to generate 2KHz Square waves on P1.0 of Port 1 using Timer 0 autoreload mo

```
      MOV SP, #54H
      MOV TMOD, # 0000 0010 B ; Timer0 mode 2
      MOV TH0, #06H
      MOV TL0, #06H
      SETB TR0 ; Start timer0
Loop : JB TF0, Compli
       SJMP Loop
Compli: CPL P1.0 ; Toggle bit P1.0
        SJMP Loop.
```

```
        ORG 0000H
        AJMP start
        ORG 000BH
        AJMP INT_TF0
Start:  MOV SP, #54H
        SETB ET0
        SETB EA
        MOV TMOD, 00000010
        MOV TH0, #06H
        MOV TL0, #06H
        SETB TR0
here:   SJMP here
INT_TF0: CPL P1.0
        RETI
        END.
```

⑦ write 8051 program to receive a serial byte through RxD

```
      ORG 0000H
      MOV SCON, #01010000
MOV TMOD, # 0010 0000
      MOV TH1, # 230 d     (1200 Baudrate)
      SETB TR1
      CLR RI
here: JNB RI, here
      MOV A, SBUF
      END
```

Transmission

```
      ORG 0000H
MOV   SCON, #01000000 B
      MOV TMOD, #0010000
      MOV TH1, # 230d
      SETB TR1
      MOV SBUF, #56 H
here: JNB TI, here
      CLR TI.
```

⑨ write 8051 prog. as example interrupt call to routine, timer 0 is used in mode 0 to overflow & set the timer 0 interrupt flag. when interrupt is generated, the program vectors to the interrupt routine, resets the timer 0 interrupt flag, stops the timer & returns.

S

```
      MOV TMOD, #00H.
      CLR TF0.
      MOV IE, #82H
      SETB TR0.
wait: SJMP wait

      ORG 000BH
      MOV EA, #00H
      CLR TR0
      RETI
```

⑩ what is the use of mode 0 of serial communication in 8051. write a program to transmit a data 45H in mode 0.

(P)

```
        ORG 0000H
        MOV SCON, #00H
        MOV SBUF, #45H.
Again:  JNB TI, Again
        CLR TI.
```