ISOTROPIC RADIATOR

In general, isotropic radiator is a hypothetical or fictitious radiator. The isotropic radiator is defined as a radiator which radiates energy in all directions uniformly. It is also called isotropic source. As it radiates uniformly in all directions. Basically isotropic radiator is a lossless ideal radiator or antenna. Generally all the practical antennas are compared with the characteristics of the isotropic radiator. The isotropic antenna or radiator is used as reference antenna. Practically all antennas show directional properties i.e. directivity property. That means none of the antennas radiate energy in all directions uniformly. Hence practically isotropic radiator cannot exist.

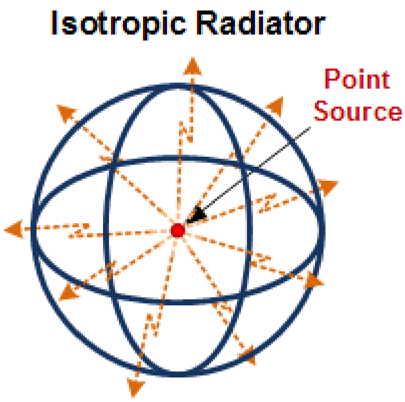


Figure 1: Isotropic radiator

Consider that an isotropic radiator is placed at the center of sphere of radius (r). Then all the power radiated by the isotropic radiator passes over the surface area of the sphere given by (4πr) assuming zero absorption of the power. Then at any point on the surface, the Poynting vector W gives the power radiated per unit area in any direction. But radiated power travels in the radial direction. Thus the magnitude of the Poynting vector W will be equal to radial component as the components in θ and ∅ directions are zero i.e. $W_\theta = W_\emptyset = 0$. Type equation here.Hence we can write,

$$|W| = W_r$$

The total power radiated is given by,

$$P_{rad} = \oint W\,ds = \oint W_r\ ds = W_\circ \oint ds = 4\pi r^2 W_\circ$$

Where

$W_\circ = P_{avg} =$ Average power density component

$\oint ds = 4\pi r^2$=surface of sphere

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

Where,

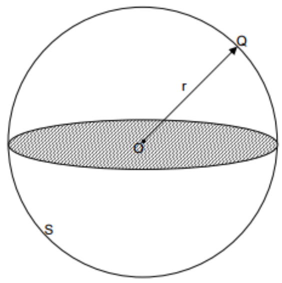
P_{rad} = Total power radiated in watts

r = Radius of sphere in meters

P_{avg} =Radial component of average power density in W/m^2

Electric Field of Isotropic Antenna

The Point source is located at the origin point O, then the power density at the point Q is given as



$$P_{avg} = \frac{\frac{P_{rad}}{4\pi r^2}\,\mathrm{W}}{\mathrm{m}^2} \ldots\ldots\ldots\ldots\ldots (1)$$

The power density is related to the electric and magnetic field

$$W = \frac{1}{2} Re|E.H^*| = \frac{E^2}{2\eta_\circ} = \frac{1}{2}\eta_\circ H^2 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $\eta_\circ = 120\pi\Omega$ the intrinsic impedance of free space

From (1) and (2)

The electric field strength is given at point Q:

$$E = \frac{\sqrt{30P_{rad}}}{r}$$

Where P_{rad} is the power radiated by the antenna which equal also to I^2R_{rad}

Isotropic antenna is a lossless antenna where $e_t = 1$ or in the other words

$P_{in} = P_{rad} = I^2R_{rad}$

Note that: for any directive antenna with gain (G) the electric field strength is expressed as

$$E = \frac{\sqrt{30P_{rad}G}}{r}$$

Directivity of isotropic antenna

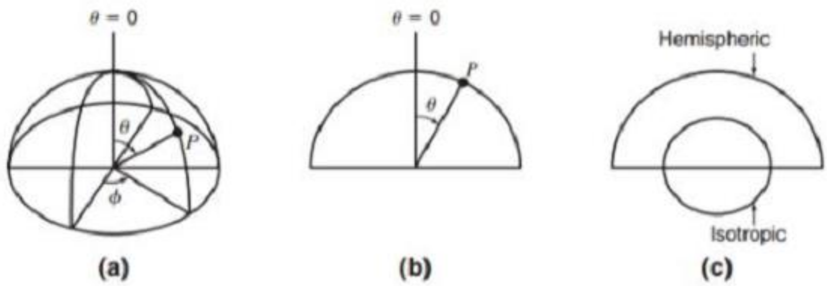
Directivity is the ratio of the area of a sphere ($4\pi r^2$) to the beam area A of the antenna

$$D = \frac{4\pi}{\iint_{4\pi} P_n(\theta,\phi)d\Omega} = \frac{4\pi}{\Omega_A} \qquad \textit{Directivity from beam area } \Omega_A$$

Where $P_n(\theta,\emptyset)d\Omega = \frac{P(\theta,\emptyset)}{P(\theta,\emptyset)_{max}} =$ the normalized power pattern

The smaller is the beam area, the larger the directivity D. For an antenna that radiates over only half a sphere the beam area A=$4\pi r^2$ (Figure 2) and the directivity is

$D = \frac{4\pi}{2\pi} = 2$ ($3.01dBi$) Where the dBi the decibels over isotropic



Hemispheric power patterns, (*a*) and (*b*), and comparison with isotropic pattern (*c*).

Note that the idealized isotropic antenna radiated over complete sphere (A=$4\pi r^2$) hence lowest possible directivity for it is

$$D = \frac{4\pi}{4\pi} = 1\ (0dBi)$$

All actual antennas have directivities greater than one (D > 1). The simple short dipole has a beam area and a directivity D = 1.5 (= 1.76 dBi).

Another way to prove the unity directivity is

$$D(\theta,\emptyset) = \frac{U(\theta,\emptyset)}{U(\theta,\emptyset)_{max}} = 4\pi\frac{U(\theta,\emptyset)}{P_{rad}}$$

$$P_{rad} = \oint U(\theta,\emptyset)\, d\Omega = \oint U(\theta,\emptyset)\sin\theta\, d\theta\, d\emptyset = 4\pi r^2 U_\circ$$

where $U_\circ$ is the maximum radiation power intensity.

Then

$$D(\theta,\emptyset) = 4\pi\frac{U(\theta,\emptyset)}{P_{rad}} = 4\pi\frac{U_\circ}{4\pi r^2 U_\circ} = 1$$

For isotropic gain equal to directivity =1

$$D(\theta,\emptyset) = G(\theta,\emptyset) = 1$$

EXAMPLE: If the electric field from an isotropic antenna at some far field observation point is 5 V/m, what is the power density in Watt/m^2, radiated power in Watt, at 100m range?

ANSWER:

$(a)\ W = \frac{1}{2} Re|E.H^*| = \frac{E^2}{2\eta_\circ} = \frac{(5)^2}{120\pi}$= 0.03315 Watt/m^2

$$E = \frac{\sqrt{30P_{rad}}}{r} \rightarrow 5 = \frac{\sqrt{30P_{rad}}}{100} \rightarrow (5)^2 = \frac{30P_{rad}}{(100)^2}$$

$$P_{rad} = 4166.67\ W$$