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COURSE ON BASIC TELECOMMUNICATIONS SCIENCE

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"ANTENNAS"

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ANTENNAS

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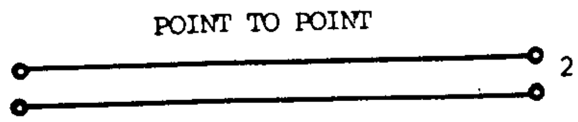
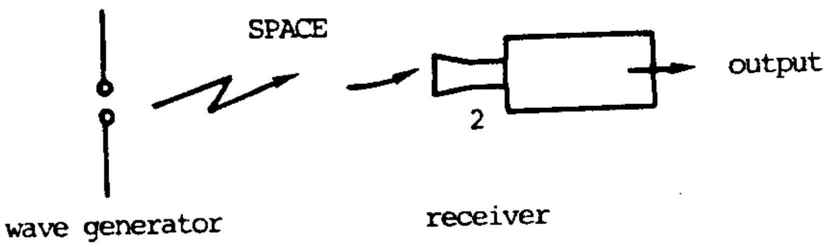
Introduction

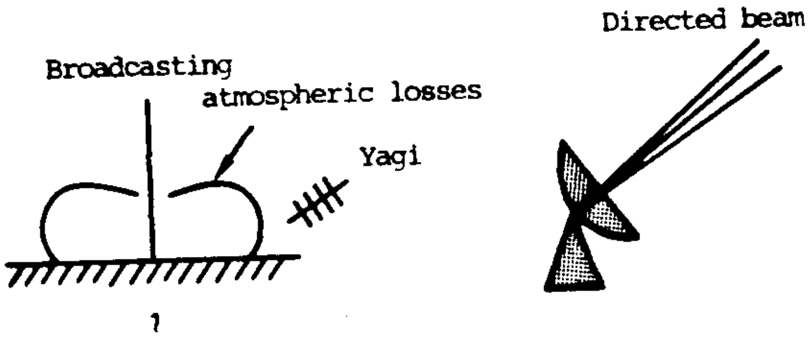
"Guided wave" communication channel



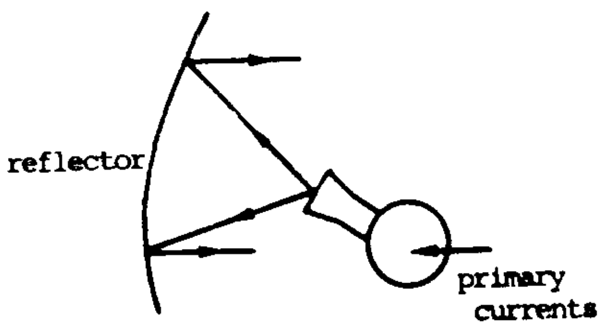
"Free space" communication channel



Distribution of radiated power

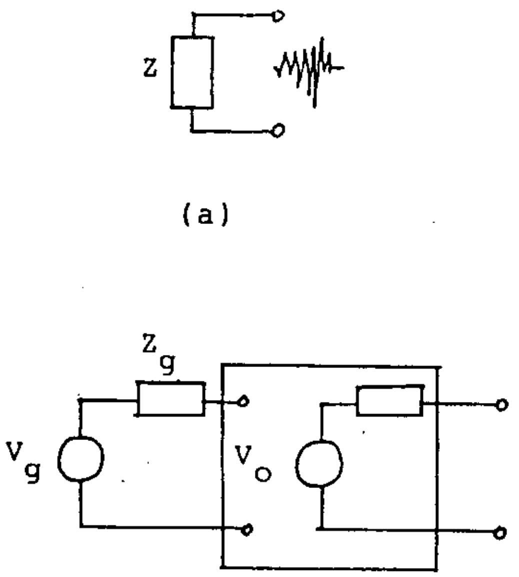


Radiating currents



9. The radar equation

Noise output



(b)

Fig. 9.1.

The thermal noise at the terminals of an impedance Z is given by (Fig. 9.1a)

$$\overline{dv^2} = 4kTR(\omega)df \tag{9.1}$$

The quadratric values add up. Let Q be the quadratic gain of the system (Fig. 9.1b)

$$Q(\omega) = \frac{|V_o|^2}{|V_g|^2} \tag{9.2}$$

If no additional noise were created the quadratic fluctuation would be

$$\overline{dV_o^2} = 4kTR_g(\omega)Q(\omega)df \tag{9.3}$$

Because of additional noise sources, a noise factor F > 1 is introduced, hence

$$\overline{dv_o^2} = 4\ k\ T\ R_g(\omega)Q(\omega)F(\omega)df \tag{9.4}$$

If the input system has n_g times as much noise as Z_g (where n_g, the noise source factor, is > 1) :

$$\overline{dv_o^2} = 4\ k\ T\ R_g(\omega)Q(\omega)\underbrace{\Big[F(\omega)+n_g(\omega)-1\Big]}_{F_{eff}}df \tag{9.5}$$

This gives (Fig. 9.2)

$$(\overline{v_o^2})_{noise} = 4\ k\ T \int_{\omega_1}^{\omega_2} R_g\ Q\ F_{eff}\ df$$

$$= 4\ k\ T\ R_g\ Q_{ref}\ (F_{eff})_{av}\ B \tag{9.6}$$

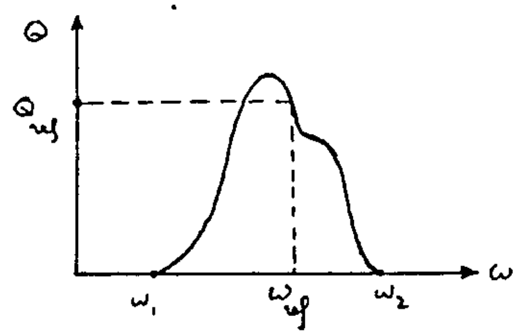


Fig. 9.2.

where

$$B = \int_{f_1}^{f_2} \frac{Q}{Q_{ref}}\, df$$

$$F_{av} = \frac{1}{B}\int_{f_1}^{f_2} F\,\frac{Q}{Q_{ref}}\, df \qquad (9.7)$$

Minimum detectable signal

$$\frac{\overline{(v_o^2)}_{signal}}{\overline{(v_o^2)}_{noise}} = \frac{Q\overline{(v_g^2)}}{\overline{(v_o^2)}_{noise}} \geqslant \min.\left(\frac{S}{N}\right)_{output} = N \qquad (9.8)$$

The minimum signal to noise ratio at the output depends on the detection method, the equipment etc ...

Radar signal

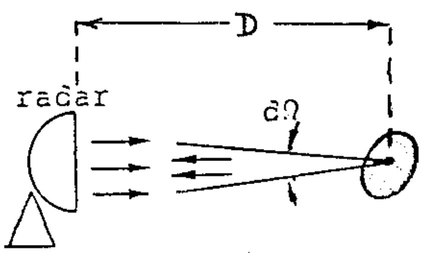


Fig. 9.3

From (2.12) the power density incident on the target is

$$W_i = \frac{\left|\overline{E_i}\right|^2}{2R_{co}} = \frac{\mathcal{P}_{tr}}{4\pi D^2}\, G \qquad (9.9)$$

where G is the gain (Dη) of the antenna. The power scattered in a solid angle dΩ is (Fig. 9.3)

$$\mathcal{P} = W_i\ \sigma_{rad}\ \frac{d\Omega}{4\pi} \qquad (9.10)$$

The solid angle of concern is, from (7.8),

$$d\Omega = \frac{S_{eff}}{D^2} = \frac{1}{4\pi D^2}\, G\ \lambda^2\ M\ P \qquad (9.11)$$

Therefore

$$\mathcal{P}_{rec} = \frac{G^2\lambda^2}{64\pi^3 D^4} \sigma_{rad} M P \mathcal{P}_{tr} = \frac{\left|\overline{v_g^2}\right|}{4R_g} \tag{9.12}$$

Radar equation

Averaged over all frequencies :

$$\boxed{\mathcal{P}_{rec} = \frac{G^2\lambda^2}{64\pi^3 D^4} \sigma_{rad} M P \mathcal{P}_{tr} \gg k T B F_{eff} N} \tag{9.13}$$

Bibliography

The literature on antennas is extensive. On an elementary level :

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List of symbols

$\bar{a}$ = magnetic potential (T m)

$\bar{b}$ = magnetic induction (T)

$c = (\varepsilon_o\mu_o)^{-0.5} = 3.10^8$ = velocity of light in vacuum (m s^{-1})

$\bar{d}$ = electric induction (C m^{-2})

$\bar{e}$ = electric field (V m^{-1})

$\bar{e}_a$ = impressed electric field (V m^{-1})

$\bar{e}_i, \bar{h}_i$ = incident fields

$\bar{h}$ = magnetic field (A m^{-1})

$\bar{j}$ = volume current density (A m^{-2})

$\bar{j}_a$ = applied volume current density (A m^{-2})

$\bar{j}_s$ = surface current density (A m^{-1})

$k_o = \frac{\omega}{c} = \frac{2\pi}{\lambda}$ = wave number in vacuum (m^{-1})

$\bar{u}_a$ = unit vector in direction $\underline{a}$

D = directivity (dimensionless)

$\bar{F}$ = radiation vector (V)

G = gain of an antenna (dimensionless)

I = current (A)

M = mismatch factor (dimensionless)

P = polarization factor (dimensionless)

$\bar{P}_e$ = electric dipole moment (C m)

$\bar{P}_m$ = magnetic dipole moment (A m^2)

R = distance to the origin (m)

$R_{co} = (\mu_o/\varepsilon_o)^{0.5} = 120\pi$ = characteristic resistance of vacuum (Ω)

S_{eff} = effective cross-section of an antenna (m^2)

W = electromagnetic energy density (J m^{-3})

$Z_a = R_a + jX_a$ = antenna impedance (Ω)

Z_L = a load impedance (Ω)

$\mathcal{E}$ = electromagnetic energy (J)