MUTUAL IMPEDANCE OF ANTENNA

While considering the self impedance of antenna, we assumed that the antenna is lossless and isolated from the other objects and ground. But many times in the large antenna systems, any antenna may be placed in the close vicinity of other active antennas. In such cases, the antenna terminal impedance is not simply equal to the self impedance of the antenna but another impedance gets introduced due to the currents flowing in other active antennas placed close to the antenna considered. Such impedance is called mutual impedance of antenna. Before discussing mutual impedance of antenna, let us consider the coupled circuits with two circuits kept very closed to each other. When current flows in circuit-1, the voltage is induced at the open terminals of circuit-2. Similarly the current flowing in circuit-2 induces voltage at the open terminals of circuit-1. It is illustrated in the Fig. 7 (a) and (b).

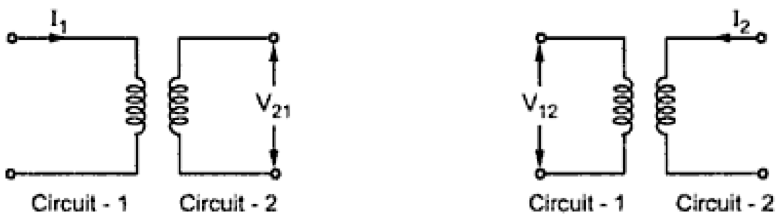

Fig 7 Representation of voltage induced in coupled circuits

Thus the mutual impedance of the coupled circuit is defined as negative ratio of the voltage induced at the open terminals of once circuit to the current in other circuit. Mathematically we can write,

$$Z_{21} = -\frac{V_{21}}{I_1} \quad \text{... (3)}$$

$$Z_{12} = -\frac{V_{12}}{I_2} \quad \text{... (4)}$$

Note that mutual impedance and transfer impedance are altogether different concepts. The mutual impedance is the negative ratio of the induced voltage in one circuit to the current in

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other circuit. While the transfer impedance is the ratio of voltage imposed in one circuit to the current in other circuit. In mutual impedance induced voltage is measured across open terminals while in transfer impedance current is measured in short circuited terminals.

Let us consider two antennas kept very closed to each other (such antennas may be called coupled antennas) as shown in the Fig. 8 (a) and (b).

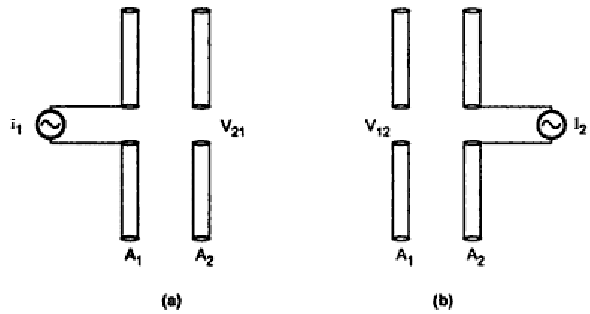

Fig 8 Coupled Antennas

Exactly on the similar lines to the coupled circuits, the mutual impedance of the antenna is given by,

$$Z_{21} = -\frac{V_{21}}{I_1} \qquad \text{... (5)}$$

$$Z_{12} = -\frac{V_{12}}{I_2} \qquad \text{... (6)}$$

But according to reciprocity theorem, we can write mutual impedance of antenna as,

$$\boxed{Z_m = \frac{V_{21}}{I_1} = \frac{V_{12}}{I_2}} \qquad \text{... (7)}$$

The mutual impedance depends on,

i) Magnitude of induced voltage,

ii) Phase difference between induced voltage and input current,

iii) Tuning conditions of coupled antennas.

Radiation Resistance

In general, an antenna radiates power into free space in the form of electromagnetic waves. So the power dissipated is given by,

$$W' = I^2 \cdot R \qquad \text{... (1)}$$

Assuming all the power dissipated in the form of electromagnetic waves, then we can write,

$$R = \frac{W'}{I^2} \qquad \text{... (2)}$$

The resistance which relates power radiated by radiating antenna and the current flowing through the antenna is a fictitious resistance. Such resistance is called radiation resistance of antenna and it is denoted by R_{rad} or R_r, or R_o.

Note: The radiation resistance is a fictitious resistance such that when it is connected in series with antenna dissipates same power as the antenna actually radiates. But practically the energy supplied to the antenna is not completely radiated in the form of electromagnetic waves, but there are certain radiation losses due to the loss resistance denoted by $R_{loss.}$ Thus the total power is given by,

$$W = W' + W'' = \text{Ohmic loss} + \text{Radiation loss}$$

$$W = I^2 R_{rad} + I^2 R_{loss}$$

$$\mathbf{W = I^2(R_{rad} + R_{loss})} \qquad \text{...(3)}$$

Note: The radiation resistance of antenna depends on antenna configuration, ratio of length and diameter of conductor used, location of the antenna with respect to ground and other objects.