UNIT II  EMI COUPLING PRINCIPLES

Conducted, radiated and transient coupling;
Common ground impedance coupling; Common mode and
Ground loop coupling; differential mode coupling; Near
field cable to cable coupling, crosstalk; field to cable
Coupling; Power mains and power supply coupling.

RADIATION COUPLING:
No conductive path exists between the
Emitter & the receptor.
The receptor lies in the far field of the emitter.
The emitter’s radiation field decays as 1/R where
R = separation distance between the emitter & the
receptor.
The radiation coupling between an
Emitter and a receptor results from a transfer of
electromagnetic energy through a radiation path.
TYPES OF RADIATION COUPLING:

- Coupling of natural electromagnetic environment to the receptor such as a Power line.
- The Power transmission line here acts as a receiving antenna.
- A receptor may also receive electromagnetic environmental noise or interference through exposed connectors and from exposed signal or other lines in the equipment or circuit.
- Coupling of electromagnetic energy from nearby equipment via direct radiation.

DESCRIPTION:
- Radiated coupling results when electromagnetic energy is emitted from a source, propagates to the far field, and induces voltages and currents in another circuit.
- Unlike common impedance coupling, no conducted path is required.
- Unlike electric and magnetic field coupling, the Victim circuit is not in the electromagnetic near field of the Source.
- Radiated coupling is the only possible coupling mechanism when the Source and Victim circuits are separated by many wavelengths.
CONDUCTION COUPLING:

DEFINITION:

A conductive path exists between the emitter and the receptor (power cords, ground returns, interface cables).

The conduction coupling between an emitter and a receptor occurs via a direct conduction path between the emitter and receptor.

Examples:

Interferences can be carried by power supply lines when emitter and receptor operate from the same power supply line.

For example, common mains power supply is a frequent source of conducted interference.

Interferences are also carried from emitter to receptor by signal or control lines, which are connected between the two.

TRANSIENT COUPLING:

Two basic interference coupling mechanisms are:

1. Radiation
2. Conduction
Examples for Interference coupling

1. Coupling of electric and magnetic fields in cable harnesses and multiconductor transmission lines.

2. Radiation from an emitter picked up by Power supply lines or signal lines connected to other equipment.

3. Radiation from Power transmission lines & from signal or control cables coupling into power or signal cables connected to other equipment.

Inductive coupling or capacitive coupling

The interference coupling in cable harnesses, multiconductor transmission lines & closed spaced wires on printed circuit boards is a result of the inductive coupling or capacitive coupling of electromagnetic energy.

The inductive coupling between two loops (current carrying conductors) is more predominant in low series impedance circuits and at lower frequencies.

The capacitive coupling is more predominant in high impedance to ground and at higher frequencies.
Radiation of electromagnetic energy can occur where cables or signal transmission lines are poorly shielded.

Radiation can also occur from exposed wires carrying signals, especially in printed circuit boards, and at exposed solder joints.

**Three Main Components of Electromagnetic Interference:**

In a transmission line connected to a source at one end and terminated in an arbitrary load at the other end, there are three main components of electromagnetic energy. These are:

1. Conducted interference - Axial wave transferring signal power from its source to the load.
2. A radial component - Supplying line losses.
3. Radiation coupling - A radiated wave which represents heat transfer from one place to another place in the form of light (wave).

**Common Ground Impedance Coupling:**

![Diagram showing common ground impedance coupling](image)
Common Ground impedance coupling

Common ground impedance coupling, in which two or more units or systems are connected to the same safety wire, ground grid or plane at more than one place.

Common impedance coupling may occur anytime a source circuit and a victim circuit share part of their respective current paths.

Consider the two simple circuits shown in fig. Each circuit has its own source, signal wire and load but they both share a wire for a signal return current.

If the shared wire had zero impedance the voltage across each circuit's load resistor would depend only on that circuit's source voltage.

However, a small amount of impedance in the shared wire causes a voltage to appear across R2 when there is a signal in circuit 1 and vice versa.

This phenomenon is called crosstalk and is generally defined.
Cross talk in dB

\[ X_{\text{talk}} = 20 \log \left( \frac{V_{\text{RL}}}{V_{\text{L}}} \right) \text{ when } V_{\text{L}} = 0 \]

To calculate the cross talk in circuit 2 due to signals in circuit 1 we set \( V_{\text{L}} = 0 \)

\[ V_{\text{L}} = I_1 R_{\text{L}} + I_2 R_{\text{L}} + (I_1 + I_2) R_{\text{RET}} = 0 \]

Setting \( V_{\text{L}} = 0 \)

\[ I_2 \left( R_{\text{L}} + R_{\text{L}} + R_{\text{RET}} \right) + I_1 R_{\text{RET}} = 0 \]

\[ I_2 = \frac{-R_{\text{RET}}}{R_{\text{L}} + R_{\text{L}} + R_{\text{RET}}} \quad I_1 \]

\[ I_1 = \frac{V_{\text{RL}}}{R_{\text{L}}} \quad \text{and} \quad I_2 = \frac{V_{\text{RL}}}{R_{\text{L}}} \]

\[ 20 \log \left( \frac{V_{\text{RL}}}{R_{\text{L}}} \right) = 20 \log \left( \frac{-R_{\text{RET}} \cdot V_{\text{RL}}}{R_{\text{L}} + R_{\text{L}} + R_{\text{RET}} \cdot R_{\text{L}}} \right) \]
\[ V_{R2} = \frac{R_{L2}}{R_{L2} + R_{S2}} \cdot V_{RET} \]

\[ = \frac{R_{L2}}{R_{L2} + R_{S2}} \cdot \frac{R_{RET} V_{R1}}{R_{L1}}. \]

\[ X_{talk21} = 20 \log \left( \frac{R_{RET}}{R_{L2} + R_{S2}} \left( \frac{R_{L2}}{R_{L1}} \right)^2 \right). \]

Ground-related interference often involves one of two basic coupling mechanisms. The first mechanism results from the fact that the signal circuits of electronic equipment share the ground with other circuits or equipment. This mechanism is called common-ground impedance coupling.

The figure illustrates a mechanism by which interference is coupled between culprit and victim circuits via the common ground impedance. In this case, the interference current will flow through the common-ground impedance, producing an interfering signal voltage \( V_c \) in the victim circuit.
It should be noted that interference caused by a current flowing in the common impedance may be due to a current that is related to the normal operation of the culprit circuit or intermittent current that occurs due to abnormal events (lightning, power faults).

\[ I_1 \]

\[ V_1 \]

\[ V_2 \]

Common Mode impedance coupling between circuits

Common mode coupling becomes a problem when two or more circuits share a common ground and one or more of the following conditions exist:

1. A high-impedance ground.
2. A large ground current.
3. A very sensitive, low-noise margin circuit connected to ground.
Two or more devices are interconnected by the power supply and communication cables. When external currents flow via these, common-mode impedances, an undesirable voltage appears. This stray voltage can disturb low-level or fast electronic circuits. All cables, including the protective conductors, have impedance, particularly at high frequencies.
The exposed conductive parts (ECP) of devices 1 and 2 are connected to a common earthing terminal via connections with impedances $Z_1$ and $Z_2$. The stray over voltage flows to the earth via $Z_1$. The potential of device 1 increases to $2I_1$. The difference in potential with device 2 results in the appearance of current $I_2$.

$$I_2 = \frac{2}{Z_2} \frac{I_1}{I_2}$$

At high frequency, the impedance of the stray capacitance between the earth and ground is low. The ground current flows thru the capacitance. The result is a multipoint ground at high frequency.
1. Reduce impedance.

2. Mesh the common references.

3. Install functional equipotential bonding between devices.

4. Reduce the level of the disturbing current by adding common mode filtering and differential mode inductors.

Common Mode and Differential Mode Coupling

Common-mode and ground-loop coupling in which radiated fields couple into ground loops that convert interference to undesired common-mode currents and to differential mode currents.

Differential-mode coupling in which radiated fields penetrate signal and control cables to develop interfering voltages at the victim.
Common and differential Mode Interferences

The electromagnetic disturbances carried by electrical power supply lines are classified into two categories:

1. Common mode currents/voltages and different mode currents/voltages.

The common mode interferences are defined as the unwanted electrical potential differences between any current carrying conductors and the reference ground.

The differential mode interferences are defined as the unwanted potential differences between any two current carrying conductors.

\[ V_C = \frac{(V_{PG} + V_{NG})}{2} \]
Where $V_{PG1}$ and $V_{NG1}$ are the voltages of phase and ground wires and neutral and ground wires respectively.

Fig. 4.7 (b) shows a balanced circuit. The sender and the receiver transformer windings have a grounded center tap.

No metallic conductor is used to connect the two grounded terminals.

If an interference voltage is simultaneously coupled to the two conductors, the voltmeter $V_1$ will not read a voltage difference, whereas voltmeter $V_2$ will.

On the other hand if the interference voltage is coupled to only one of the lines, then both voltmeters $V_1$ and $V_2$ will read a voltage difference. This is the differential mode of interference.

The conducted EMI can be injected into the lines to simulate either common-mode disturbances or differential mode disturbances.

A back filter prevents the injected EMI from reaching the mains supply or any apparatus other than the receptor.
Examples of Coupling: Conducted EMI

Common Mode

Cable to cable coupling and cross talk.

Differential Mode

two wires or cables are run close to each other.

Parallel Conductors

Fig shows two lengths of cable or (other conductors) that are running side by side.

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capacitance between them, called stray capacitance
a time varying signal in one wire can couple
via that capacitance into the other wire.
That is referred to as capacitive coupling.

Another mechanism of cable to cable
coupling is mutual inductance.
Any wire carrying a time-varying
current will develop a magnetic field around it.
If a second conductor is placed near enough
to that wire, that magnetic field will induce
a similar current in the second conductor.
That type of coupling is called
inductive coupling. Mutual inductance makes the
cables behave as if a poorly ground
transformer were connected between them.
In cable to cable coupling, either or
responsible for the existence of an interference condition. Though there is no physical connection between the two cables, the properties make it possible for the signal on one cable to be coupled to the other.

Inductive Coupling

Either or both of the properties cause the cables to be electromagnetically coupled such that a time varying signal present on one will cause a portion of that signal to appear on the other.

The efficiency of the coupling increases with frequency and inversely with the distance between the two cables!