Optical Fibers for mitigating EMI issues -An Overview

Uma S[#1], MallanaGowda N[#2]
[#1] Assistant Professor, Dept. Of ECE, SJBIT, Bengalooru, India
[#2] Assistant Professor, Dept. Of EEE, TKIET, Waranagar
Dr. Ambedkar Institute of Technology, Bangalore
[1]uma.shivanna@gmail.com
mallupatil567@gmail.com

***Abstract*— As electronic devices become increasingly sensitive and proliferate in number, electromagnetic interference (EMI) to and from these devices is becoming increasingly important. EM1 can create several problems in electronic systems, such as ground loops, system safety, cross talk, common mode noise, and differential mode coupling. Over the years several techniques have been developed to solve these problems. However, they are cumbersome, impractical, inefficient, and expensive. The fiber optics technology offers an excellent solution to overcome EM1 problems altogether. This paper introduces the salient features of fiber optics [1], as an alternate solution to EM1 problems. This paper focuses on the fundamentals of fiber optics technology and how it can be used to eliminate EM1 from electronic systems.**

***Keywords*—- EMI, EMC, Optical Fiber cable.**

I. INTRODUCTION

A. Definition of EMI & EMC

EMI (Electro Magnetic Interference) is the term to describe the interaction of electrical and electronic equipment with its electromagnetic (EM) environment and with other equipment. EMI is concerned with emissions and immunity of electronic devices. All electrical devices generate emission and are susceptible to EM phenomena such as lighting-induced transients, electrostatic discharges, electrical fast transients, radio frequency fields generated by transmitters and hand-held communication devices.

EMC (Electromagnetic Compatibility) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects (EMI) that such energy may induce. The goal of EMC is the correct operation, in the same electromagnetic environment, of different equipment which use electromagnetic phenomena, and the avoidance of any interference effects.

In order to achieve this, EMC pursues two different kinds of issues. Emission issues are related to the unwanted generation of electromagnetic energy by some source, and to the counter measures which should be taken in order to reduce such generation and to avoid the escape of any remaining energies into the external environment. Susceptibility or immunity issues, in contrast, refer to the correct operation of electrical equipment, referred to as the victim, in the presence of unplanned electromagnetic disturbances.

B. Causes of EMI

Many electromagnetic compatibility problems are caused by low immunity to emissions and poor facility and data wiring and grounding which further affect equipment performance. Besides, radiated and conducted emissions generated by a piece of equipment may also affect the equipment's own performance and other sources of EMI result from faulty grounding or bonding contacts.

The origins of EMI are electrical, with the unwanted emissions being either conducted (voltages or currents) or radiated (electric or magnetic fields). For EMI to occur, 3 essential elements must exist: an electrical noise (EMI) source, a coupling path, and a victim receptor. The coupling path from a source to a receptor can be in 1 of 4 categories: conducted (electric current), inductively coupled (magnetic field), capacitively coupled (electric field), and radiated (electromagnetic field). More details will be given below about the sources and receptors. EMI can occur in 2 different situations: intersystem EMI and intrasystem EMI. Intersystem EMI occurs between 2 or more discrete systems while intrasystem EMI occurs between elements in the same system.

C. Relevance of EMI in Power Electronic Devices

Power Electronics can be split into a Power and an Electronic circuit. The power circuit converts an unregulated input power from AC or DC type to a regulated AC or DC voltage or current and delivers it to a load. The electronic circuit controls the converter by measuring the input and output voltages and/or currents and generates signals for the power circuit. In a power electronic system, the flow of electric energy is controlled based on a load demand. In a power electronic system, line and EMI filters are important sections of a system. There are different load and utility requirements, which should be fulfilled to reduce noise and harmonic levels of the system. Main aims in modern power electronic systems are to deliver the power with maximum efficiency, minimum cost and weight in an integrated circuit.

In Power Electronics, high voltages and high currents, are processed by fast switching to reduce losses, which are significant sources of electromagnetic noise, and it cause additional costs. Main EMI research targets in power electronics are:

- Analysis of electromagnetic emissions by measurements, modelling and simulations
- Development active EMI filters in high power converters to suppress EMI noise

Two major sources of EMI in power electronics are dv/dt and di/dt during switching times. In fact, a DC voltage of few hundred volts is chopped by a power switch in a fraction of microsecond. Thus, conducted emission is a major issue in most power electronic systems due to significant over voltage and leakage current generated by fast switching and stray components of the system.

• High di/dt may create significant over voltage in power converters due to stray inductance of current loops

• High dv/dt may create significant leakage current in magnetic elements and electric motors due to stray capacitive coupling between windings and a frame

II. OPTICAL FIBERS

Fiber optic technology is simply the use of light to transmit data. The general use of fiber optics did not begin until the 1970s. Robert Maurer of Corning Glass Works developed a fiber with a loss of 20 dB/km, promoting the commercial use of fiber. Since that time the use of fiber optics has increased dramatically.

A. Features of Optical fiber cable

A fiber optic cable consists of a glass silica core through which light is guided. This is covered with a material with a refractive index of slightly less than the core. This is called the cladding. The refractive index of the cladding need only be around 1% less than the core to achieve the total internal reflection necessary to confine the light to the core. Although it was stated earlier that the real benefit of fiber optic cable over copper was virtually infinite bandwidth, Benefits of fiber include:

- High bandwidth for voice, video and data applications
- Optical fiber can carry thousands of times more information than copper wire. For example, a single-strand fiber strand could carry all the telephone conversations in the United States at peak hour
- Fiber is more lightweight than copper. Copper cable equals approximately 80 lbs./1000 feet while fiber weighs about 9 lbs./1000 feet
- Low loss. The higher frequency, the greater the signal loss using copper cabling. With fiber, the signal loss is the same across frequencies, except at the very highest frequencies
- Reliability - Fiber is more reliable than copper and has a longer life span
- Secure - Fiber does not emit electromagnetic interference and is difficult to tap

B. Optical fiber Construction

Optical fiber is composed of several elements. The construction of a fiber. Optic cable consists of a core, cladding, coating buffer, strength member and outer jacket. The optic core is the light-carrying element at the center.

The core is usually made up of a combination of silica and germanium. The cladding surrounding the core is made of pure silica. The cladding has a slightly lower index of refraction than the core. The lower refractive index causes the light in the core to reflect off the cladding and stay within the core as shown in Fig 1.

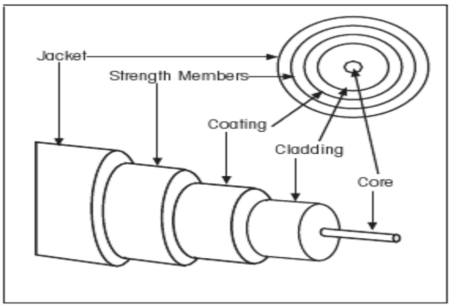

Fig. 1 Optical fiber construction

C. Types of Optical fiber cable

The two main types of fiber in use today are multi mode and single mode fiber. over the diameter of the fiber as shown in Fig 2. Single mode fiber has a very small core causing light to travel in a straight line and typically has a core size of 8 or 10 microns. It has unlimited bandwidth that can go unrepeated for over 80 km, depending on the type of transmitting equipment. Single mode fiber has enormous information capacity, more than multimode fiber.

Multimode fiber[2], supports multiple paths of light and has a much larger core and has a core size of 50 or 62.5 microns. The light travels down a much larger path in multimode fiber, allowing the light to go down several paths or modes. Multimode fiber can be manufactured in two ways: step-index or graded index.

Step-index fiber has an abrupt change or step between the index of refraction of the core and the index of refraction of the cladding. Multimode step-index fibers have lower bandwidth than other fiber designs.

Graded index fiber was designed to reduce modal dispersion inherent in step index fiber. Modal dispersion occurs as light pulses travel through the core along higher and lower order modes. Graded index fiber is made up of multiple layers with the highest index of refraction at the core. Each succeeding layer has a gradually decreasing index of refraction as the layers move away from the center.

High order modes enter the outer layers of the cladding and are reflected back towards the core. Multimode graded index fibers have less attenuation (loss) of the output pulse and have higher bandwidth than multimode step-index fibers.

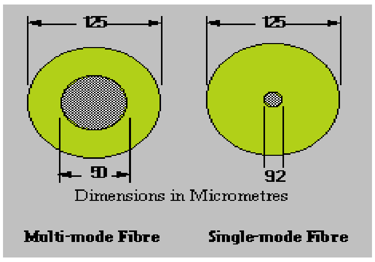

Fig. 2 Types of Optical fiber

III. EFFECTS OF EMI

Electromagnetic interference[9], can be caused by electrical appliances in poor condition or not grounded correctly. Electrical equipment that produces a great deal of energy, like industrial generators. Certain devices, notably arc-welders. Medical equipment including MRI devices, therapeutic radiation, and TENS (pain-control devices). Electronic gadgets like AM Radio.

A. In Electrical Components

Possible sources are electric motors, switches, and other electronic gear. Alternators produce a whining or whistling sound in radio receivers that varies with engine speed and output current. It is less noticeable when the batteries are fully charged. Removing the alternator belt and running the engine can help determine if this is the cause of the EMI. There are filters specifically designed for alternators, as well as most of the other devices that cause EMI. Voltage regulators[5], produce noise that sounds pretty much the same as alternators except that it will vary only with alternator output, and not with engine speed.

Starting motors are another common source of EMI. These motors generate electrical pulses while they are cranking. The pulses are then picked up by the boat's wiring harness and conducted to the electronics equipment. These voltage spikes can be very damaging to electronic devices. There are products specifically designed to not only protect the electronics, but also to provide a stable source of DC voltage, preventing equipment crashes.

DC electric motors are a major source of EMI [10],as a result of poor contact between brushes and slip rings or commutators.

Other sources of EMI result from faulty grounding or bonding contacts. These can usually be found on metal cabinets, electric motor housings and other electrical device enclosures. The prop shaft is another likely source if the grounding brush contacts are dirty or worn. If the problem persists, a thorough check of the boat’s grounding and bonding system is in order.

B. In Electronic Components

Power electronic converters[6], are widely used in many applications including renewable energy generation, industrial equipment/motor drives, electric vehicle/train, air-craft, household appliances, electronic ballasts, computer power supplies, power supplies for telecommunication equipment, etc. These power converters use the fast switching power semiconductor switches, such as MOSFET (Metal-oxide semiconductor field effect transistor), IGBT (Insulated Gate Bipolar Transistor) as the preferred switching devices as they have many properties, such as higher efficiency, smaller size, and lower overall cost, low losses associated with switching device[7]. However, fast switching speed of new converter/inverter technologies has the potential to cause EMI and high dv/dt .

All power electronics equipments generate and emit unwanted electrical signals (EMI noise)[11], that can lead to performance degradation of other electrical/electronic equipments. They generate high frequency conducted and radiated EMI noise and draw distorted line currents due to the sharp edges of the switching waveforms with high dv/dt. The undesirable EMI effects are interference with wireless systems (e.g., radio, TV, mobile, data transmission), malfunction of biomedical equipments (e.g., cardiac pace maker), misbehavior of security doors of banks, ABS brake systems of cars, and electronic control systems in airplanes and the increase in power system losses associated with improper performance or failure of a range of industrial power equipments. It is necessary to find a mitigation technique to overcome this problem and to avoid costly equipment failures in industry.

High-frequency switching operations in power electronic devices has improved the dynamic performance of ac motor drives, but created unexpected problems, such as motor bearing damage, high levels of conducted EMI, breakdown of winding insulation and motor leakage currents. It has been proven that its time derivative, dv/dt, as well as common mode voltage generated in ac drives are responsible for most of these problems .

In most of the previous work, passive EMI filters have been employed to reduce the effect of EMI noise and high dv/dt in power converter. However, in designing passive filters the compensating bandwidth is comparatively narrow and only a certain part of noise can be eliminated. The size, weight, temperature, and reliability issues are significant design constraints. Active EMI filters provide alternative approaches to the problem .Further investigation into noise sources and coupling path is desirable, as well as more accurate identification of noise propagation.

IV. METHODS OF REDUCTION OF EMI

The best solution is to identify the source device and to correct the condition there. If that's not possible, then you have to use separation, shielding or filtering.

Shielding means enclosing the source or affected devices, or both, in a metal enclosure which is connected to the boat's ground. The radiated energy is absorbed by the shield and conducted to ground. If the equipment has a metal cabinet, the cabinet is simply grounded. Otherwise, the equipment must be enclosed in a metallic screen or foil. In the case of wires, the conductor may be replaced by a shielded cable. Techniques that are currently used to improve the shielding performances of light materials such as plastics and composites are: the insertion of conducting meshes in the substrate, the use of conducting additives and fillers prior to injection moulding and the use of conducting coatings. Among these techniques the use of conducting coatings allows the realization of lightweight shields. Thin coatings of conducting material, having thickness of a few micrometers, can provide good shielding performances in the radio-frequency range, up to a few gigahertz. The deposition of such coatings on polycarbonate foils leads to a new concept of lightweight thermoform able shield, which can be used to reduce EMI from and against printed circuit boards (PCBs) in electronic devices.

Earthing of electrical systems is required for a number of reasons, principally to ensure the safety of people near the system and to prevent damage to the system itself in the event of a fault. The function of the protective conductor, or earth, is to provide a low resistance path for fault current so that the circuit protective devices operate rapidly to disconnect the supply. When talking about grounding it is actually two different subjects, earth grounding and equipment grounding. Earth grounding is an intentional connection from a circuit conductor usually the neutral to a ground electrode placed in the earth. Equipment grounding is to ensure that operating equipment within a structure is properly grounded. These two grounding systems are required to be kept separate except for a connection between the two systems to prevent differences in potential from a possible flashover from a lightning strike. The purpose of a ground besides the protection of people plants and equipment is to provide a safe path for the dissipation of Fault Currents, Lightning Strikes, Static Discharges, EMI and RFI signals and Interference.

A filter is a circuit that allows some frequencies to pass while other frequencies are blocked or shunted to ground. Filters usually employ capacitors, inductors, or both, depending on their design and intended use.

V. SWITCHING FROM COPPER CABLE TO FIBER OPTIC CABLES

In recent years it has become apparent that fiber-optics are steadily replacing copper wire as an appropriate means of communication signal transmission. They span the long distances between local phone systems as well as providing the backbone for many network systems. Other system users include cable television services, university campuses, office buildings, industrial plants, and electric utility companies. A fiber-optic system is similar to the copper wire system that fiber-optics is replacing. The difference is that fiber-optics use light pulses to transmit information down fiber lines instead of using electronic pulses to transmit information down copper lines. Looking at the components in a fiber-optic chain will give a better understanding of how the system works in conjunction with wire based systems.

A. Block diagram and explanation of fiber optical signal transmission Interface

A fiber optic interface generally consists of five major functions as shown in Fig 3. On the transmitter side, a circuit processes the input signal in order to drive the electro-optical converter. This converter, which can be an LED or a laser diode, generates the signal-dependent light intensity modulation, and its mechanical case eases transmission of the signal into the fiber. At the fiber end, a pin diode converts the optical signal back into a low electrical current. The low-noise transimpedance preamplifier converts the current signal into a voltage and also amplifies it to an acceptable level. Because the photodiode input signal can vary in amplitude, and AGC amplifier adjusts the peak-to-peak signal level to 1.4Vp-p and restores the DC level for no signal to 0V. The quality of a fiber optic interface is characterized by several factors such as signal-to-noise ratio, linearity, bandwidth, power consumption, and transmission distance. The S/N ratio should be at least 50dB for analog systems to achieve an image that is free of noise. In conventional designs, there are basically two ways to improve the S/N ratio. One is to increase the diode drive current, which, though, leads to higher harmonic distortion. The second is to use a very low-noise transimpedance amplifier as a receiver. Both alternatives increase the component count and add manufacturing costs. The approach circuits presented here, however, are a new to simplifying and minimizing the design of an analog fiber optic interface and to provide an interface that is more integrated and offers lower power consumption.

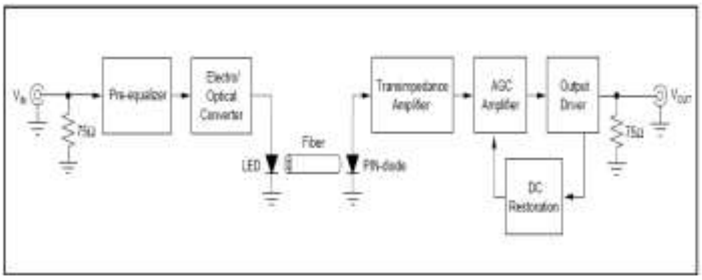

Fig. 3 Block diagram of Optical fiber signal Transmission Interface

VI. APPLICATIONS IN VARIOUS FIELDS

A. Medical Applications

The advent of practicable optical fibers has seen the development of much medical technology. Optical fibers have paved the way for a whole new field of surgery, called laproscopic surgery (or more commonly, keyhole surgery), which is usually used for operations in the stomach area such as appendectomies. Keyhole surgery usually makes use of two or three bundles of optical fibers. A "bundle" can contain thousands of individual fibers". The surgeon makes a number of small incisions in the target area and the area can then be filled with air to provide more room.

One bundle of optical fibers can be used to illuminate the chosen area, and another bundle can be used to bring information back to the surgeon. Moreover, this can be coupled with laser surgery, by using an optical fiber to carry the laser beam to the relevant spot, which would then be able to be used to cut the tissue or affect it in some other way. Medical applications of the optical fibers are summarized in one term: Scopes This term includes image taking and retrieval from inside the patient's body, and then put on a monitor. This has great advantages in assessing a patient's condition or even in performing inner surgeries or tumour destruction.

B. Laser Applications

Many of the medical applications of lasers involve the use of a high-power beam of laser radiation to coagulate various tissues, that is, to produce a small sealing scar, or to cut tissue. To understand the medical applications of lasers, one must understand how laser light interacts with human tissue and what effects can be produced.

C. Modern Computer Applications

Small laser beams are used in printing devices to trace reproducible images. Laser-etched discs are used for large-capacity audio, video, and data recording and playback. From the almost explosive popularity of CD-ROMs for personal computers to the entertainment industry's feverish desire to get a full-length motion picture onto a single 5-in. CD, optical memory, in one form or another, is spreading in leaps and hounds, mostly at the consumer level. The next generation of super density (SD) disks using shorter wavelength visible diodes is making its statement in the new market. Smaller integrated-circuits feature sizes now down to 0.25 pm make use of deep UV microlithography systems. Excimer-laser stepper is used in for the production of dynamic-random-access-memory (DRAM) chips. Lasers are also used for drilling of holes in print heads for ink-jet printers. Also lasers are used for local interconnection of computers. Laser based information displays; display hologram and laser Video-projection systems are other important applications.

D. Telecommunication Applications

Until the optical fiber network was developed, telephone calls were mainly sent as electrical signals along copper wire cables. As demand for the systems to carry more telephone calls increased, simple copper wires did not have the capacity, known as bandwidth, to carry the amount of information required.

Optical fibers offer huge communication capacity. A single fiber can carry the conversations of every man, woman and child on the face of this planet, at the same time, twice over. The latest generations of optical transmission systems are beginning to exploit a significant part of this huge capacity, to satisfy the rapidly growing demand for data communications and the Internet.

The main advantages of using optical fibers in the communications industry are:

- A much greater amount of information can be carried on an optical fiber compared to a copper cable.
- In all cables some of the energy is lost as the signal goes along the cable. The signal then needs to be boosted using regenerators. For copper cable systems these are required every 2 to 3km but with optical fiber systems they are only needed every 50km.
- Unlike copper cables, optical fibers do not experience any electrical interference. Neither will they cause sparks so they can be used in explosive environments such as oil refineries or gas pumping stations.
- For equal capacity, optical fibers are cheaper and thinner than copper cables which make them easier to install and maintain.

E. Other Applications

Another important application of optical fibres is in sensors. If a fibre is stretched or squeezed, heated or cooled or subjected to some other change of environment, there is usually a small but measurable change in light transmission. Hence, a rather cheap sensor can be made which can be put in a tank of acid, or near an explosion or in a mine and connected back, perhaps through kilometres of fibre, to a central point where the effects can be measured.

Fibre optics are also used to carry high power laser beams from fixed installations within factories to the point of use of the laser light for welding, cutting or drilling. The fibre provides a flexible and safe means of distributing high power laser radiation around a factory so that robots or machine tools can be provided with laser machining[3] capability

The Earth's atmosphere is a big problem for astronomers. It is a gas that is constantly moving which makes the light traveling through it from distant starts flicker. If astronomers could use a reference 'star' whose brightness they knew, then they could allow for this twinkling.

The telescope will look at how the atmosphere is effecting the artificial star second by second and adjust the telescope's mirror to compensate. This should allow astronomers to capture pictures of astronomical objects of a quality previously only obtainable from the Hubble Space Telescope. The optical fiber in this case is used to pipe the laser power needed to create the artificial star from the lasers to the telescope itself. It also does not interfere with other instruments that do use electricity. For this reason, fibre-optics is also becoming very important for short-range communication and information transfer in applications situations like aircraft. This application is now being extended into motor cars, and plastic optical fibres will soon (say in 5-8 years time) be very common for transmitting information around the car.

VII. CONCLUSIONS

Electromagnetic Interference that is generated in power electronics or power devices can be reduced by using Fiber optical cables. Optical fiber cables are more advantageous over copper cables as discussed above, it has higher bandwidth and has capability of long transmission.. Optical fiber cable reduces noise or any other external interference that add up to the devices by providing proper protection.

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