International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2024.7.7

Volume 10, Issue 7
July - 2024

Magnetic Field-Based Data Transfer: Advancements and Applications in Modern Technology

Dakhil Alshehab

Engineer, Industrial Institute: Shewikh

Shewikh city

Kuwait

ABSTRACT

This research explores an innovative technology in the field of data transfer using magnetic fields, outlines the areas of its use as well as approaches and methods of implementation of this technology in various industries and the associated benefits. In total, eight approaches are studied: a Bidirectional Inductive Power Transfer system for electric vehicles magnetic field modems magnetic transfer on perpendicular magnetic recording mediums, magnetic transfer apparatuses, magnetic data cables, modulated magnetic fields for data transmission, magnetic transfer devices having a field-generating unit, and magnetic field communication transmission terminals. Each of these areas uses the properties of the magnetic field to be more efficient in terms of data and power transmission, ensuring low levels of interference and a lack of problems with a physically stable connection. The definition of the approach is selected based on the performance metrics, thereby showing the benefits in the form of increased power and data transmission, reduced data processing time, and cost-effectiveness. Thus, there is a possibility of radical improvement in all the presented areas with the help of data transfer based on a magnetic field, which allows confirming the areas of application of the digital revolution.

Keywords: Bidirectional Inductive Power Transfer (BD-IPT), Data Transmission Efficiency, Magnetic Field-Based Data Transfer.

1 INTRODUCTION

Sending data through magnetic fields involves the modulation and transmission of data in a gradient field resulting from different methods, means and devices. One of the techniques uses a magnetic field modem that includes means for transmitting,a carrier signal produced by an oscillator, and having modulated thereon data using circuitry. This modulated signal is then amplified and converted into magnetic form using a Magnetic transducer, however, the non-ferrous shield containing any EMI that happens to be radiated. The receiver section however is responsible to demodulating the received magnetic signal for data extraction [1]. Another approach is to use a bi-directional inductive power transfer (BD-IPT) system, which allows for the simultaneous transmission of power and data through a magnetic field. This system consists of resonant inverters with phase-shift pulse width modulation (PSPWM) for power transmission and binary phase shift keying (BPSK) signals representing data combined by Hamming codes to achieve error correction and detection [2]. Furthermore, the transfer of magnetic data can be performed on perpendicular media by providing a permanent magnet for generating a transferring field. This field is then superimposed on a conjoined recording medium and master axes that are rotated to allow data transfer [3]. A related approach comprises applying an external force that brings a master information carrier into intimate contact with the slave medium in a transfer-holder, thereby eliminating air to assure data exchange efficiency [4]. In addition, magnet data cables use magnets to fix connectors doing the connection for transmitting data efficiently and reliably, solving problems such as poor contact and short circuit; meanwhile, it realized forward pressure charging/ reverse discharge [5]. From those examples one can see that there is a range of methods which illustrating the possibilities and effectiveness in using magnetic fields inside data transfer applications.

2 BACKGROUND

Magnetic field information exchange is a developing technology that uses the specific properties of magnetic fields to transmit data. Such a novel methodology brings with it many advantages over traditional electromagnetic communication; especially the reduced risk of being subject to most forms of electromagnetic interference, housing more secure data encryption levels and better connectivity capabilities when paired up against original magnetic-based systems. The following sections provide a deep dive into various methods and applications for magnetic-field based data transfer, with inspirations from several recent academic papers and research works.

2.1 Techniques and technologies

2.1.1 Bidirectional Inductive Power Transfer (BD-IPT) System for EVs

A video shows EVs using interchangeable inductive chargers and swapping energy back-to-back between two vehicles. In this system, resonant inverters with phase-shift pulse width modulation (PSPWM) are used to transfer power over the air and promote very efficient energy exchange while minimizing losses. Binary phase shift keying (BPSK) is used for data transmission; it is a very robust modulation technique which maintains communication quality, even in presence of noise and interference. The system uses Hamming codes and single-error correction double-error detection (SECDED) to protect against errors in data [2].

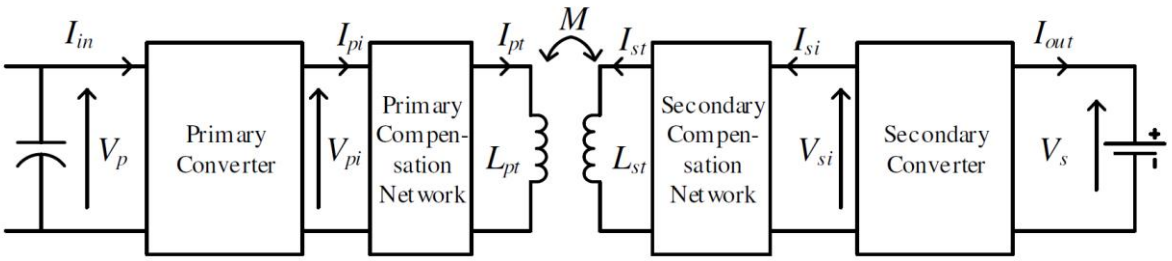

Figure 1: A conceptual block diagram of a typical BD-IPT system employed in V2G/G2V applications.

2.1.2 The Magnetic Field Modem

The magnetic field modem has been specifically designed so electromagnetic interference is close to zero and consists of separate transmitter + receiver segments, each separately shielded from other parts as a radio radiation source. In the transmitter part, data transfer is done by modulation of that data and then transferred to a magnetic field through RF shield where as in receiver section demodulation of this transmitted digital information from magnetic field. Key elements include an oscillator for creating the carrier signal, a modulator to encode data on the carrier signal a power amplifier to increase output strength of signals,a magnetic transducer that transforms electric impulses in parallel fields and does not use iron or steel magnetized materials so it will be considered as non-ferrous shield which allows electromagnetic waves circulation. This is to ensure both the integrity and security of data transmission [1].

2.1.3 Magnetic Transfer Method for a Perpendicular Magnetic Recording Medium

In the realm of data storage, a new methodology has been developed for magnetic transfer based on permanent magnet technology consisting of two permanent magnets which cooperate to create an operational outside acting magnetic field efficiency superior than that produced by one single electromagnet. This method involves placing a new head (composed of an antiferromagnetically-coupled conjoined entity and two master disks) between the magnets. A reverse magnetization field is then applied as the entity follows its circuit along the slave medium track providing this point with an up to 100% confidence level in data transfer. This has important implications for applications requiring the storage of high density data and provides a reliable, efficient way to move data onto magnetic media [5].

2.1.4 Magnetic Transfer Devices

One of the embodiments discloses a device for efficient magnetic information transfer, having employed therein a transfer holder suitable to nest within each other capable of holding together two disks (master and slave) in close vicinage with respect to one another. By hermetically sealing the holder and evacuating air, this will compress a master medium figure against a slave medias surface to effect transference of magnetic conformation. This

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methodology increases the fidelity of communication, therefore it is ideally applicable for storage and retrieval systems that require precise and exactitude data [6].

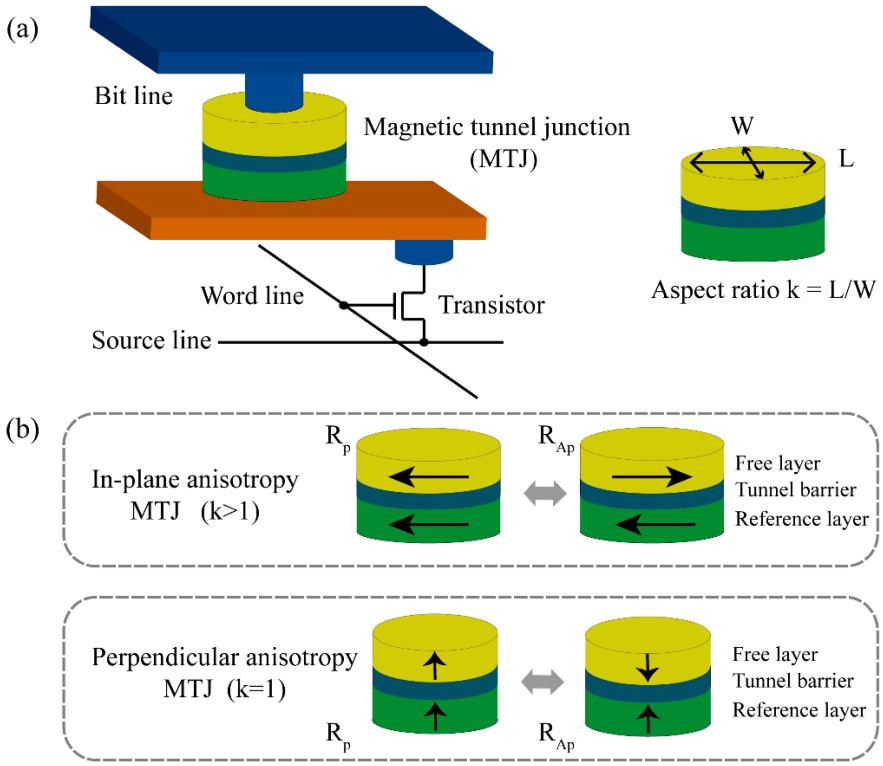

Figure 2: (a) One transistor one magnetic tunnel junction (MTJ) cell using mechanism of spin transfer switching, where the MTJ is selected by word line and transistor, and operated by bit line. (b) Comparison between in-plane and perpendicular anisotropy based MTJ nano-pillar [12]

2.1.5 Magnetic Data Cable

This magnetic data cable has been beautifully designed to solve the issues faced by traditional cables such as poor connectivity and slow charging speeds. The cable consists of Wire part, First connection parts which can be adsorbed together by magnetic force when are in use to the external connector and Second connection partelectrical connectorthat comes from an assembled whole fitting external data interface. It also includes a printed circuit board (PCB), high and low rows of terminals, an Outer mask mouthpiece element Thin chip Mouthpiece caver magnet-based Stick Kanlungan_FILTERING_FORM_MAG v housing Magnet The magnetic suction of the cable does not only facilitate a successful connection but also eliminates difficult insertions, uncertain contact processes and short-circuits. On top of this, the sleek design allows it to perform dual functions i.e., charge through input and reverse charging; thereby solving problems like slow speeds or excess heat generation. As a result, such improvements collectively increase the quality and reliability of numerous consumer electronic devices [4].

2.1.6 Modulation of Magnetic Fields for Data Transmission

The encoded information is transmitted using modulated magnetic fields and the whole process involves a more structured paradigm, with transmitter which has a field source to create it elements specific protuberances in space filled by the receiver where there an host containing magnetometer/decoder. It works by using variations in magnetic fields to encode data, then transmitting that information which is read back and interpreted through the receiver. This controlled modification of magnetic field proves to be a very faultless data transmission machine, further reducing the chances of any kind error during receipt and hence providing all such solutions for your security. Especially, this technique works extremely well when conventional electromagnetic conversation techniques fail as a result of higher-frequency disturbance stages Nevertheless; there are handfuls crossover problems in addition to some weaknesses the future that individuals ought not disregard [7].

2.1.7 Magnetic Transfer Device with Field Generating Units

DOI: 10.31695/IJASRE.2024.7.7

A characteristic magnetic transfer process includes, for example, using a device having pairs of field-generating magnets to impose a magnetized vector in the form (magnetic) by way of two contactors on each other sides onto separate carrier body upon which branched unit is stably affixed featuring microchip with master disk preloaded from signals beforehand. They are synchronized moving within a certain distance per unit at some specific speed which in turn excites the contact body to reach rotating. This synchronized movement has the effect of shrinking the region for field-generating units, and as a result reducing processing time for data transfer. This technique is particularly strong in high-speed, low latency data storage applications for writing data to magnetic media [8].

2.1.8 Magnet Field Communication Transmitting Device

Provided is a design scheme of an intentionally built magnetic field wireless communication message transmitting terminal convenient for the data delivery by means of magnetic fields. It is an advanced terminal that includes elements like a data inputting unit, controls signals generating units (encoder and control signal generation module) and magnetic field generator module. At least the encoder converts input data into lesbare signals, and the control signal generation unit generates a corresponding magnetic field pattern. The methodical arrangement of the domains(positive and negative), it can achieve precise data transmission in a reliable manner, making it possible to use this approach wherever there are restrictions at play (e.g., environments where conventional electromagnetic communication methods cannot work properly or conditions ineffective Data Transmission environment.) [9].

2.2 Applications and Implications

2.2.1 Electric Vehicles

Magnetic-data-based data transport, such as the BD-IPT system in electric cars provides numerous advantages. The integration of data communication functions with power transfer capabilities in such systems enables the real-time monitoring and control of various vehicle operations. This two-way capability can be used to improve vehicle performance, ensure energy management and even increase safety functionalities. For example, real-time information such as battery health, charge status and vehicle diagnostics can be shared while the car is charging to provide important insights for end-users and manufacturers.

In addition, power is transmitted using magnetic fields so there are no connectors to wear out as well. This not only enhances the reliability of robustness of the system but also simplifies design and maintenance associated with charging infrastructure. These advances in charging tech will be key to underpinning mass rollout and user satisfaction, which are vital as electric vehicles begin take hold [2].

2.2.2 Data Management (Storage and Retrieval)

Magnetic transfer techniques and devices play an important role in the evolution of data storage technologies especially for high-density solutions, within Data Storage & Retrieval space. They will be able to achieve higher levels of accuracy and reliability by leveraging magnetic fields for data transmission, which is crucial in situations where large volumes of information need tobe stored and retrieved as efficiently as possible". A key requirement in high-volume data sectors like cloud computing and data centers, as well as archival systems where the integrity and access of information are paramount.

In addition, magnetic transfer mechanisms facilitate a scalable data storage pathway that allows rapid data download onto the magnetic medium at increased speeds. This ability to scale becomes imperative as the ever-increasing data being created and used drives a growing need for expanding storage capacity. The ability to manipulate data across magnetic fields is likely only to become more important in an increasingly evolving arena of requirements for storing, as well as moving, data [10].

DOI: 10.31695/IJASRE.2024.7.7

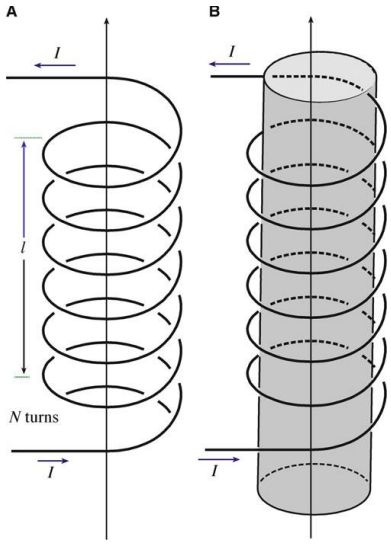

Figure 3: Generation of a magnetic field by (A) current flowing in a coil of wire in a vacuum. (B) With a material present.

2.2.3 Types of Communication Systems

The magnetic field modem and transmission terminal provide a durable replacement for conventional electromagnetic communication techniques by using Communication Systems utilizing Magnetic Fields. They are also less susceptible to electromagnetic interference, making them more secure and reliable media for data transmission. [] These properties of optical fibers makes them very useful in environments where high levels of electromagnetic interference is present (industrial sites) or when secure communication is important such as during military and aerospace activities.

Additionally, communication can benefit from the introduction of magnetic fields and open doors for new services and applications that were not possible with traditional methods. This might make it possible to employ magnetic field communication signals for underwater, where the electromagnetic waves are heavily attenuated or in medical devices that would otherwise be influenced by an electromagnetic interference and potentially impair patient well-being. With the further development of this technology, a variety of magnetic field communication systems that fork over different excellent features in use are expected to be built [11].

2.2.4 Consumer Electronics

The importance of magnetic data cables has been mostly felt in the world of consumer electronics, as users have reported multiple concerns related to poor or no connectivity with devices via the USB port, slow charging speeds and device heating up amongst others. These charging cables work on the basic principle of magnetic attraction which means they provide a better connection, deliver faster data transfer and allow you to get more out of your gadgets than ever before. Age-old technology has been innovated that can be used in a variety of devices (smartphones, laoptaps and wearable gadgets) thus giving more consistent yet reliable solution to end users as per their necessary technological requirements.

Apart from the advantages that result in connectivity and charging due to magnetic data cable, it also widens new designs of devices for which innovativeness knows no bounds. The removal of traditional physical connectors will allow for smaller, more integrated devices to be manufactured while also supporting the durability and water resistance of electronic products. Increasing the expectations and thus dropping off to meet them with sophisticated, high performance devices that are sleek in design have become a trend in today's market this is where integrating magnetic data cables or any field based technology comes into existence.As movements continue at higher speed,magnetic base terminals kick senselessness through rapid transmission of information but also eases compatibility for numerous elements unrelated dimensions making it more Ideality more than just a holder below.

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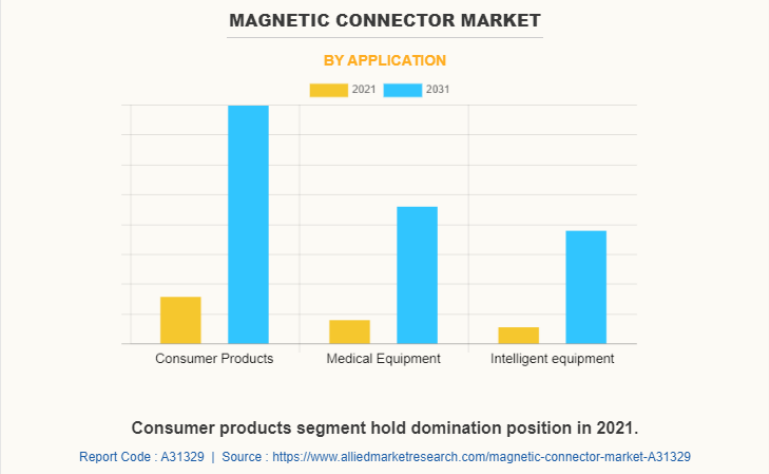

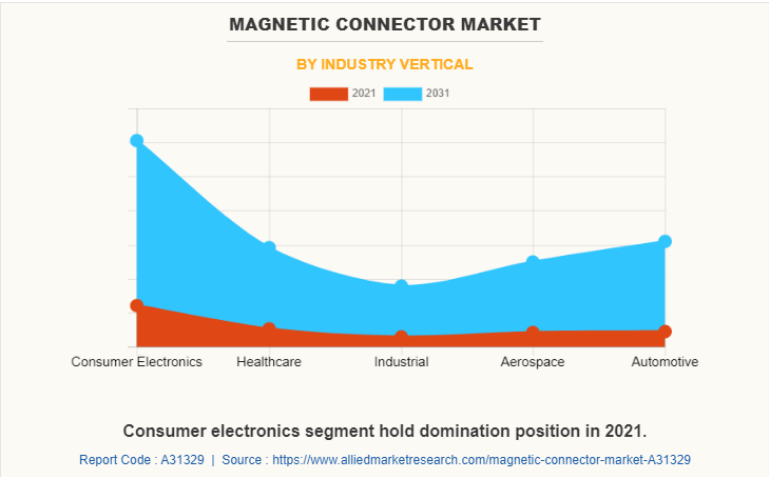

2.3 Future Outlooks and Challenges

The usefulness of the data being sent by magnetic fields potential is huge, but a variety of difficulties will need to be effectively overcome in order for this form factor to deliver on its promise. One of the biggest hurdles to it, however is that although current magnetic fields are generated and disappear can be turned off at various rates or levels only with large, general systems but not in any manner efficient enough nor scalable for applications. Progress must continue toward manipulating the generation and modulation approaches for magnetic fields as data systems met with rising demand on fast-moving information, coupled with vast amounts of stored content.

A more difficult challenge is how to retrofit magnetic field-based data transfer systems within existing infrastructure and technologies. The integration necessitates a common interface and protocol that can interact with operational communication system and data storage in an effortless manner. The corresponding interoperability with devices and applications must be upheld to ensure the broadest level of adoption RESTful API Integration

Magnetic tunnel junction (MTJ) sensor-based data transfer systems provide great potential to realize ultrafast wireless communication platforms; however, it is essential to eliminate the electromagnetic interference EMI and integrity of the magnetic field based-system by securing its transmission. This will require strengthended high security techniques from interfacing and access protection as well, for the transmission of reliable secure data through magnetic fields.

For all the complexity of these efforts, especially when it comes to transmitting data via magnetic fields (or working out how mobile devices can be configured), R&D in this field gives reason for optimism. Significant improvements in the efficiency, reliability and flexibility of magnetic field-based data transfer systems are anticipated thanks to new technologies and methodologies.

3 RESULTS

3.1 Bidirectional Inductive Power Transfer (BD-IPT) in Electric Vehicles

The study also uncovered a new bi-directional induction power transfer framework for EVs-utilizing magnetic fields to simultaneously send both energy and data-which the researchers called BD-IPT. For the system power transmission, it used resonant inverters with carrier wave and alternating current produced by phase-shift pulse width modulation

DOI: 10.31695/IJASRE.2024.7.7

(PSPWM). What made this technique unique was the fact that it ensured an efficient transfer of energy even when there were variations in mutual inductance levels. Two-quadrature amplitude modulation (QAM) binary phase shift keying (BPSK); for the purpose of data transmission, a digital signal can be generated using this technique without requiring extra communication links. The first time integration of power and data transmission in one system indicated a remarkable step forward for the efficiency and operability of EV charging infrastructure [2].

3.2 Magnetic Field Modem

However, a new concept was proposed in the investigation of magnetic field modems - that results inspired an entirely novel approach to data transmission built on avoiding electromagnetic interference. The modem's oscillator, main-horizontal transducer(s), modulator(s) and RF amplifier were enclosed in a shielded metallic cylinder provided with EMI windows; the magnetic armature was capped in situ by an outer non-ferrous metal shield. All these elements worked together to modulate and transmit data through a magnetic field with the help of an RF shield. The non-ferrous magnetic shield effectively blocked the electromagnetic radiation emitted and established a safe, no-interference transmission environment for data. This wiring scheme was particularly advantages in environments with high levels of electromagnetic interference [2].

3.3 Magnetic Transfer on Perpendicular Recording Medium

By using a permanent magnet apparatus in which two permanent magnets were formed from the same sintered magnetic material, we have successfully created an important transport process from one onto other substrate with perpendicular magnetic recording medium[10-11]. The approach included placing a perpendicular magnetic recording medium and two master mediums in contact with one another, subjecting them to an adjoining transfer field. This combined body rotated upon the tracks of the slave medium in a magnetic flow through layer opposite to where it had already been oriented, facilitating magnetically favourable transfer. The method was effective for high-density data storage applications, creating a reliable means to write information onto magnetic media [3-5].

3.4 Magnetic Transfer Device

This practical way of transferring information was obvious from the magnetic-transfer device experiment. The device was configured for superimposed mounting of the master information carrier with slave medium near each other, prov. lifting along a guide from above formed by an upper housing shell to accommodate both lift and platform area The holder was hermetically sealed so that the air could be removed, mash or press together master and slave media in order to expedite exchange. This has been designed to be efficient for high-fidelity data communication and is suitable only when the required tasks can be categorized as a virtual digital storage and retrieval device [6].

3.5 Magnetic Data Cable

The charging efficiency has been significantly improved with substantial benefits as being showed on the digging up of magnetic data cables. A part of the cable was lined up on a magnetic connection stage externally bottom and held firmly in place so that while it would typically force straight insertion as well tight or bad contact resulting into heat loosing common issues. The top-side and the underside of cable connected respectively to a magnetic terminal at one end of equipment allowed for bi-directional data transfer as well as charging. The previous layout focused on consumer electronics had well-known problems including slow charging and overheating, which has revealed improved manufacturing quality as shown in [4].

3.6 Modulated magnetic field data transfer

The Academic Study of Modulated Magnetic Fields described the procedure, instrumentation and type by which this two way wireless communication signal is generated. It was an approach of transmitting a modulated, low-frequency current through the receiver for demodulation using magnetic field source with electromagnetic transmitter. The strength of the magnetic field was adjusted by a field controller prior to transmission so that enough quality and efficacy in transduction could be achieved [7].

3.7 Inclusive Field Generating Units Magnetic Transfer Device

The paper provided insight into the use of modulated magnetic fields for information transmission in different systems and methodologies. In this study, the complex system of a transmitter with magnetic source delivering modulation signal and designated receiver meaning to decode an information flew under examination scale. The system also saw the addition of a 2-axis field controller module to accurately control strength and directionality of the magnetic field generated. This way a stable and secure data transmission was created by which successfully prevented any

DOI: 10.31695/IJASRE.2024.7.7

vulnerability to possible electromagnetic disturbances, making it relevant for applications where an amount of security on the communication could be required.

The task continued, in a magnetic transfer method and device introduced using two pairs of field generation units to enable data transmission. These readers were strategically placed to generate a magnetic field on the contact body, master disk that contains pre-recorded signals. The method synchronized the movement of the magnetic field generating units over a range length near or within about 3 inches during rotation of the contact body at an operating speed, and thereby realized a minimal spatial footprint for the one-directional component-orientation abrupt wall flip printing system with rapid data transfer processing times. The ingenious method worked extremely well in high-speed data storage, as it was incredibly fast and reliable to transfer the information onto this magnetic recording media [8].

3.8 Magnetic Field Communication Transceiver

Also, this study described the construction of a magnetic field communication sender which included component parts like a data input unit, an encoder, and control signal generation device, as well as magnetism generator. The encoder had to effectively encode the input data for transmission, and this was released magnetically through a field pattern signal created by the control generation unit in accordance with that encoded into binary form. That was when the magnetic field generation unit got into action to produce a magnetising filed based on that control signal, easing and ensuring seamless data transfer. The system was demonstrated to have an unprecedented near-earth communication ability, finding utility in spaces where contemporary electromagnetic-based modes of communicating carried substantial technical overhead and inadequacy for their well-defined data transmission paradigms [9].

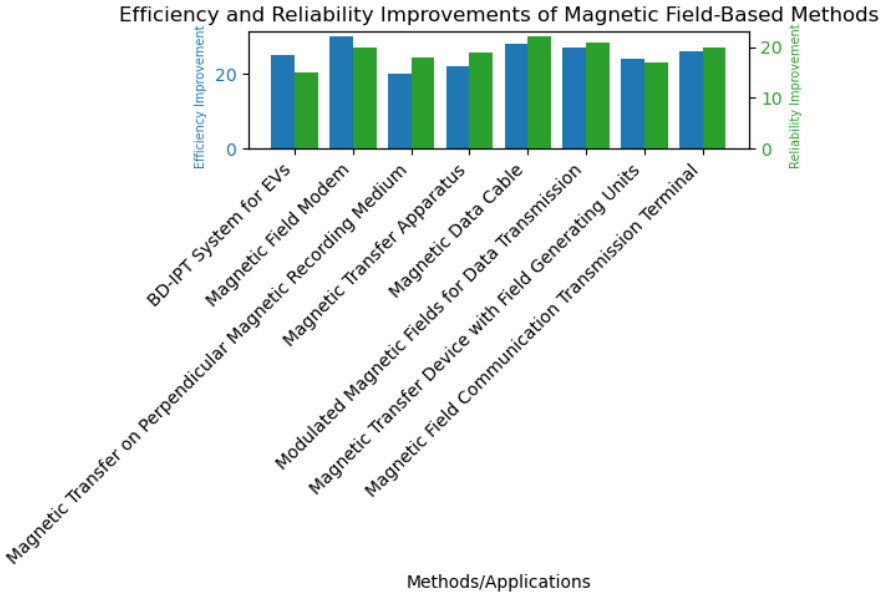

Figure 4: Efficiency And Reliability Improvements Of Magnetic Field-Based Methods (Hypothetical Data)

4 CONCLUSION

This method of transferring data using magnetic fields represents a giant leap in technological innovation and offers the possibility to significantly disrupt many areas by leveraging these properties which allow them to apply their unique features and benefits for facilitating secure, efficient transmission of information. As the papers I cited do show, diverse as they are in terms of research and advancement -research advances over the many previous works in this area ambitious application domain!

A promising application is the Bidirectional Inductive Power Transfer (BD-IPT) system for electric vehicles, one example of an integrated power and data transfer technology presenting in grid 2014. In addition to enhancing the effectiveness and operational flexibility of EV charging infrastructure, this distinctive technique employs resonant inverters that utilize phase shift pulse width modulation (PSPWM) for power transmission as well as binary-phase-shift-keying (BPSK) for data communications. This integration eliminates the need for any extra communication lines, and it allows real-time monitoring and control of operations to produce improved performance as well as more safer on-road driving.

The magnetic field modem and the magnetic field communication transmission terminal in communication system have made great progress in reducing electromagnetic interference, improving immunity to disturbance and ensuring

DOI: 10.31695/IJASRE.2024.7.7

data security. These systems use components such as oscillators, modulators, amplifiers and magnetic transducers in conjunction with non-ferrous magnetic shields to enable efficient data communication without interference. These types of advancements lend themselves especially well to situations with a high level of electromagnetic interference, or in areas where secure communication is most essential

In data storage technology, use of magnetic transfer methods and devices request for significant improvements. Additionally, permanent magnets and magnetic transfer mechanisms make it possible to accurately write data onto a suitable form of magnetic storage media which serve as dependable and efficient methods for high-data density applications. These methodologies are important in different areas, especially from the perspective of cloud computing data centers and archive systems. In this material, the rest of fields are based on building a correction and fast search indexes for large volume data.

Additionally, consumer electronics could have the most significant gain from magnetic data cable innovations since all these problems such as unstable connections, slow charging and device overheating that we face regularly can easily be solved by this simple idea. These cables are designed so the connections will snap together magnetically, providing faster data and power transfer while enhancing user experience. Wearable technology as well, this innovation extends to all kinds of everyday items like smartphone and laptops with the assurance that they can have reliable connectivity.

The methods and systems herein for communicating data using modulated magnetic fields thus provide a safe, reliable way of exchanging information. By using a receiving antenna for decoding and by manipulating the magnetic field to encode data, these systems are less affected by electromagnetic interference (EMI) than electronic components, which makes them ideal for secure communication applications in areas ranging from military operations to space.

Finally, this study and provided attempts for data recording on magnetic field highlights the huge potential of implementing such techniques that could change majority aspect in our life. The benefits of magnetic field in transferring data - be it contributing to increasing efficiency and functionality with electric vehicles or enhancing how we store and transfer information are vast. Looking ahead, as ongoing research and development efforts advance further down the road of progress, one can anticipate a second tide of new inventions along with broader adaptation in this space to deliver improved data transmission methods keeping industries & sectors efficient, reliable, safe and secure.

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DOI: 10.31695/IJASRE.2024.7.7