Surveillance Technologies

Miscellaneous

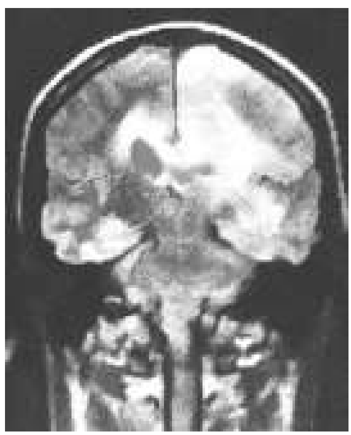
Section

5

Miscellaneous Surveillance

16

Magnetic



1. Introduction

Magnetic detection is not the topic of conversation around the dinner table, and isn't discussed at length on television as are other detection technologies such as pinhole cameras and hidden microphones. It is nevertheless an important aspect of surveillance in many fields, including law enforcement, geosciences, traffic analysis, search and salvage, hotel and conference management, and medical research, diagnostics, and treatment. It is also widely used for retail and premises security and to protect materials from theft in bookstores and libraries.

Magnetic properties are inherent in many materials and some substances, like *lodestone,* can come out of the ground with good magnetic properties. When electricity is applied to a material with good conductivity, such as copper or iron, it is possible to create an *electromagnet*. Since biological organisms generate electrical currents, magnetic activity is also associated with living things and can be detected with sufficiently sensitive devices. Thus, it is a versatile technology that applies to both living and nonliving targets.

NASA space technology has contributed to the development of magnetic resonance imaging (MRI) systems which allow the internal structure of a body to be visualized as in this image of the human central nervous system. [NASA news photo, released.]

Magnetic imaging can be achieved by organizing magnetic sensors in arrays or by taking repeated readings at quick intervals. Magnetic imaging machines tend to be large, sensitive, advanced technologies, and are used mainly in research and medical diagnostic fields.

Magnetic detection is often used in conjunction with other technologies to provide a 'bigger picture' of the phenomena that are being investigated. This chapter describes some of the smaller, portable magnetic detectors and some of the large, sophisticated room-sized magnetic imaging systems that are used for various types of surveillance.

2. Types and Variations

When we refer to *electromagnetic energy*, it doesn't have the same meaning as when we separately refer to the phenomena of *electricity* and *magnetism.* Electromagnetic energy is a collective term for radiant energies that include light, X-rays, gamma-rays, and radio waves. Electricity and magnetism are phenomena 'outside' the definition of the electromagnetic spectrum. Electricity and magnetism are so closely interrelated that they are almost always discussed together; however, surprisingly, the fact that they are related was not empirically established until the early 1800s.

electricity - a fundamental phenomenon at the atomic level that has attractive and repulsive properties that are too small for us to see directly. However, they can be observed through their effects or mathematically inferred from physics experiments. At a macro level, electricity can be channeled in conductive materials to provide electrical power for activating and running surveillance devices. Electrical activity stimulates attractive properties that can be easily observed in some materials when they are rubbed. Electrical activity always has an associated magnetic field around the area of electrical activity, which is why electricity and magnetism are almost always discussed together.

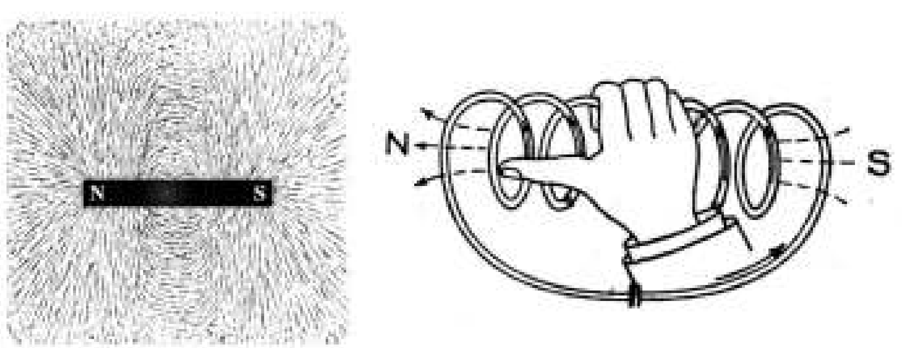
static electricity (sometimes called *stationary electricity*) - a phenomenon that can be observed in a glass rod, for example, if it is rubbed with silk so that it can briefly pick up small pieces of paper. While the glass can be made to exhibit a 'magnetic attraction' to the pieces of paper, it is not inherently magnetic in the same sense as 'lodestone,' which is a natural magnet. In other words, lodestone can exhibit fairly strong magnetic properties without the application of electricity and without being rubbed but the glass rod needs to be stimulated in order to exhibit the attractive properties.

magnetism - a physical phenomenon consisting of an attractive or repulsive force inherent in an object or stimulated by the application of an electric current. Some substances have naturally strong magnetic characteristics and can retain these characteristics for a long time. These are called *permanent magnets*. Others can be stimulated to exhibit strong magnetic forces, such as an iron nail wrapped with conductive wires that is stimulated by electricity to form an *electromagnet.* Some materials will retain their magnetism after having been stimulated with electricity. Others lose the magnetism and only exhibit magnetic properties when the electricity is applied. Some natural structures exhibit very low-level electrical activity, such as nerve impulses, and thus generate a low-level magnetic field associated with the electrical activity. Conversely, electrical activity can be stimulated in materials with a moving magnet.

All magnets have magnetic poles in pairs. By convention, they are designated as *north* and *south* poles. You cannot have one without the other. If you cut a magnet, each of the pieces will also have poles in pairs. The diagram on the following page illustrates magnetic *lines of force* emanating from the poles of a simple magnetic bar. Iron filings can be sprinkled around a magnet to illustrate the general direction of the magnetic lines of force associated with that magnet to make the phenomenon easier to see.

The lines of force will vary depending on the shape, size, and strength of the magnet and on other neighboring magnetic forces. These lines are not fixed in one position. If you resprinkle the filings over the same magnet, they will line up in the same basic configuration but will be in slightly different positions each time. The filings themselves have their own attractive, repulsive properties that cause them to orient themselves in lines. The actual force should be visualized as more of a continuous field than a series of lines, more like a light from a floodlight that radiates and extends out indefinitely but becomes gradually fainter as you move farther from the source of the light.

Whenever you have an electrical current running through an object such as an electric wire, there is a magnetic field associated with that current. The direction of that magnetic field, as the *axis of rotation,* is always the same in relation to the flow of the current. Since it's hard for many people to remember the correct direction, Fleming came up with a memory aid based on the right hand. By extending the thumb and fingers as shown in the diagram below, the thumb can be used to represent the current's direction of flow, with the curved fingers then indicating the rotational direction of the magnetic field associated with the current. Fleming's Rule is now commonly known as the *right-hand rule*, a memory aid that it is widely taught in introductory math and science classes.



Left: An illustration of a theoretical bar magnet and its associated lines of force. Right: The 'right-hand rule' in which the thumb is used to indicate the direction of an electrical current. The directional rotation of the associated magnetic field is indicated by the direction in which the fingers are curving. [Illustrations ca. 1909 and ca. 1914, public domain by date.]

Polarity is the direction of the magnetic influence of a magnet, typically designated as *north* and *south* as shown in the above diagram. Since *fields of the same polarity repel* each other (try holding two bar magnets together in one direction and then in the opposite direction) and *fields of the opposite polarity attract* one another, polarity can be used to devise compasses, magnetic detection systems, and various types of technical instruments. There are lines of magnetic force emanating from the Earth in somewhat regular patterns in a north-south orientation. The north-seeking needle of a magnetic compass orients itself toward the Earth's magnetic north, near the North Pole, aiding in navigation. Polarity is not always fixed. Over very long periods of time, the Earth's polarity apparently can switch. On a smaller scale, the polarity of an electromagnet can be changed by altering the direction in which current is applied, a concept applied to the design of electric generators.

Magnetic sensing can be used as a *passive technology*, in which the sensor seeks out sources of magnetism without generating a magnetic field. It can also be used as an *active technology*, in which a source of magnetism is intentionally applied or inserted in materials in order to track their presence, movement, or other characteristics.

Magnetic materials vary, depending on the application. Metals, ceramics, and certain polymers have sufficient magnetic properties to be used in a variety of magnetic sensing technologies.

Magnetic Access and Tracking Systems

Scientists have discovered that they can control vibrational frequencies by applying magnetic fields, thus allowing magnets to be used in marking and tracking systems. This principle has been applied to the development of *tags* or *markers* that can be attached to articles and vehicles. A magnetized strip, patch, or tape can be combined in a small package with a resonator in such a way that it has a specific signal. The resonant frequency, and thus the signal, can be altered or deactivated to change it. This allows materials to be 'checked out' of a store or library by deactivating them so they don't trip the exit sensor/alarm. The field can be reestablished if or when the article is returned.

Magnetic Security Systems

Fraud and counterfeiting with new high-resolution photocopy machines have become problems in recent years. Currency, stock certificates, sports and music concert tickets, coupons, and various other negotiable items are vulnerable to this type of copy fraud. Magnetic security features have been developed for use in documents and other materials. Since magnetic particles can be quite small and magnetic sensors can be designed to be sensitive to trace amounts of these particles, it is practical to use magnetic properties in document surveillance systems. The magnetic or magnetizable particles can be applied as a coating after a document has been produced or they can be embedded in the fibers or inks during the fabrication of the materials themselves. The magnetic assessment of documents can be done in a number of ways, and may include

- detecting whether or not a magnetic force is present or absent;
- detecting a particular pattern of magnetism, like embedding a magnetic watermark, in order to give the material a group magnetic 'signature;' or
- detecting a random or ordered pattern of magnetism that has been mathematically analyzed and coded to produce a unique signature, somewhat like a checksum is established in a block of computer data.

3. Context

Magnetic Surveillance Strips

Magnets are easy to manufacture and control, so they work very well for tracking goods and maintaining inventory. Configurable magnetic strips and buttons are widely used to protect products in retail stores and materials in storehouses and libraries. Because magnets can be made small and inconspicuous, they have many surveillance applications.

Magnetic strips are also easy to attach to cards and keys and thus are used for many different types of access control including bank cards, credit cards, door control systems, computer access control, and hotel, trade show, and office key systems.

Computer floppy discs have magnetic surfaces in which the magnetic bits are arranged and rearranged to store data and instructions. The same process can be used to program and reprogram access cards, data cards, and electronic keys. This is an important aspect of surveillance which is discussed further in later sections because it means that an electronic data record of all aspects of the use of a data card or key can be tracked and stored through computer networks.

Access Devices

Magnetic strips provide a relatively easy way to design access switches for buildings and vehicles. Most of these switches have two components that slide or swing past one another. Depending on the system, when magnetic contact is broken, or if the state of the sensor changes, the device can trigger a light, an alarm, or an electrical impulse. These devices can be placed on doors, windows, safes, garages, and on appliances. Thus, if a door, window or lid is opened or an appliance is moved or lifted, the sensor reacts by sounding an alarm. Magnetic reed switches, which are commonly used for windows and doors, can often be wired in series. Some use radio frequencies to alert a central console if the magnetic sensor is triggered.

Magnetic Cards and Keys

Magnetic strips can be embedded in cards and keys to store data that can be read or written. When combined with ‘smart card’ technology, which may include a tiny programmable circuit board on the chip, the magnetic strip becomes an accessory to the programmable circuit.

Magnetic cards and keys are used to access accounts, vending machines, phones, doors, vehicles, and anything else which can be automated to accept card data. They can also be used to store data about individual employees, conference attendees, or clients at an amusement park or casino. They can serve as a reference for medical information or medications or as identification cards. They may also be combined with other technologies to track a person’s movements.

Detection of Magnetic Materials

Many materials exhibit measurable natural magnetism, which allow them to be distinguished with magnetic sensors. A simple magnet can itself be a sensor. Many coin machines distinguish one coin from another based on attributes such as size, weight, and magnetic properties.

Magnetic sensors have recently been used to aid in traffic-monitoring projects related to construction and urban traffic flow. Magnetic sensors can be installed on bridges and causeways to monitor vehicle volume and speed.

Magnetic detectors are often used in the process of locating hazardous, unexploded ordnances (military supplies) such as land mines and bombs. They may also be used to locate terrorist bombs in urban areas or on public transportation systems. Occasionally they are used to locate or identify explosive devices created by teenagers who undertook dangerous projects without realizing their full implications. Thus, magnetic detectors are frequently used in law enforcement, public safety, and military contexts. They are also used in the geosciences to study terrain and various geophysical phenomena. Due to their ability to help assess geophysical features, they are further used by forensic scientists and archaeologists to assess underground structures, terrain, and anomalies that may indicate bones, graves, artifacts, or other objects of interest.

Small-scale magnetic detectors have some limitations when used to sense weak magnetic differences. This is partly because portable systems are subject to interference from the Earth, which generates its own magnetic field. It is difficult to shield a portable detector from this interference. Thus, the data from a small-scale magnetic detector are rarely as distinct and clear as the data from a large-scale heavily shielded system. Thus, small-scale magnetic detectors are often used in conjunction with other probes such as ground-penetrating radar and seismic detectors.

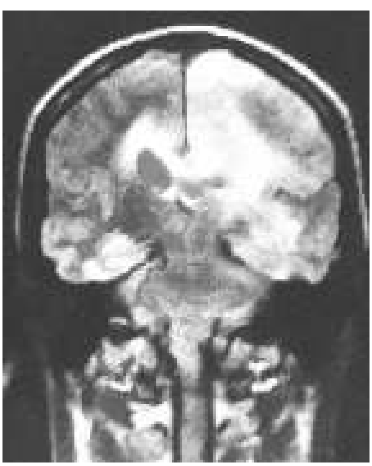
Data from multiple sensors are especially important in situations where incorrect readings could endanger lives. Thus, magnetic sensors may be used with acoustic and X-ray sensors in situations where multiple explosives are present. By cross-referencing the data from different systems it is sometimes easier to classify, confirm, and locate hazardous materials.

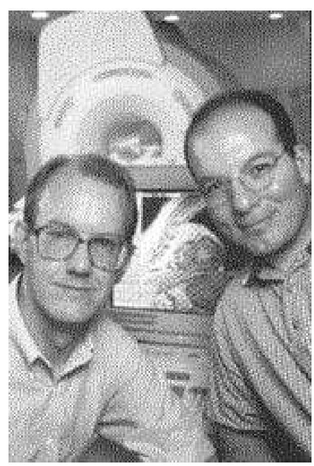
Magnetic sensors and electromagnetic sensors used together can be quite good at detecting certain classes of explosives, sometimes with a 90% detection rate. The problem is that they will also detect and flag many false alarms which can confuse the search. Thus, the data are sometimes computer processed to try to reduce the incidence of false alarms.

Magnetic Resonance Imaging

Not all magnetic detectors are limited in their ability to detect objects of interest. With the right electronics, shielding, and equipment, extremely sensitive magnetic devices can be built.

Magnetic resonance imaging (MRI) technology is an advanced and expensive technology that is currently used mainly in the field of medical diagnostics and treatment monitoring, although it has also had some interesting archaeological applications, such as examining the inside of a mummified corpse.





Left: There have been a number of magnetic detection and satellite imaging technologies developed through the various NASA space programs. Satellite imaging developed at the Stennis Space Center in the 1980s has contributed to Magnetic Resonance Imaging (MRI) which is now extensively used in medical diagnostics and patient monitoring. Right: Jerry Prince and Nael Osman, the engineers who invented the HARP-MRI system (shown in the background). [NASA 1994 news photo; Johns Hopkins University 1999 news photo by Keith Weller, released.]

MRI pictures can take some time to process, so engineers have been seeking ways to create systems that provide faster results. These are particularly suitable for assessing conditions such as heart attacks. The Harmonic Phase Magnetic Resonance Imaging (HARP-MRI) system is one that brings us a step toward faster imaging which can be more specifically used to measure cardiac function. The HARP-MRI system was developed at Johns Hopkins University and allows data to be processed in minutes rather than hours. It is the goal of the designers to continue to develop the technology until realtime images are possible, in which case a whole new dimension in imaging and diagnostics will open up.

Magnetoencephalography (MEG) is a subset of magnetic imaging which concentrates on detecting and imaging the magnetic activity of a brain. MEG differs from MRI in that it provides a near-realtime picture of the magnetic activity of a brain, whereas MRI provides a anatomical picture of the inner structure of the organ. The Massachusetts Institute of Technology (MIT) announced in 1997 that they had installed a MEG system built by the Kanazawa Institute of Technology (KIT).

In Section 2, the *right-hand rule* was introduced as a way to relate magnetism to the direction of the flow of electrical current in an object. This magnetic flow is also associated with biological nervous systems. The direction of current through neurons generates an associated magnetic field with certain predictable properties. A *biomagnetometer* is a sophisticated piece of equipment designed to detect and image this faint but distinctive magnetic field allowing us to view a 'picture' of an organism's nervous system activity. The magnetic detection coils used in MEG machines are aligned closely together and bathed in liquid helium to bring them down to extremely cold superconducting temperatures. Superconducting quantum interference devices (SQUIDs) make it possible to create the extremely sensitive magnetometers necessary to monitor fine resolution activity as is found in the brain.

In operation, the coils are placed very close to the surface of the organism to record the electrical activity. The brain's electrical activity is detected by the coils by inducing a current which can then be transformed into a printed or displayed image. The sensitivity of these systems is amazing. The coils can respond to magnetic energy as small as a single quantum. Because of this high sensitivity, the mechanism can only be used in an environment that is highly shielded in order to screen out sources of interference such as the Earth's magnetic field, which is a billion times stronger than the signal from the brain that is being measured.

MEG technology is currently used in a number of studies, including mapping the sensory and motor regions of the brain. By stimulating various parts of a body, the resulting magnetic activity in the corresponding part of the brain can be observed. At MIT, MEG technology is being used to study relationships between cognitive neuroscience and linguistics.

As the technology for magnetic resonance advances, it may become possible to build less expensive machines that can be used for a wider variety of applications.

Detection and Common Sense

There are many tragic stories associated with the detection of bombs and mines when using magnetic and other detectors. These occur even when the nature of the explosive device is suspected. A momentary lapse of reason seems to unfortunately overcome people at times, with irrevocable results. One example is a police officer with bomb detection experience who was called to investigate a suspicious device found in a car and laid on a driveway. For some reason the officer went to pick up the box, which exploded with tragic results. Another example is a soldier with land mine-detection experience working with a colleague and a mine-sniffing dog. The dog alerted to the presence of the mine and, to the horror of his buddy who was nearby, the service member touched the mine which exploded. In retrospect we can only assume they had a moment where they weren't thinking. No matter what type of detector is used, whether it's magnetic, electrical, or biological, if the person handling the technology doesn't exercise a certain amount of care, the results can be tragic. Since magnetic technologies are often used to detect explosives, suspect devices should never be picked up or handled until confirmatory equipment and procedures are put in place.

4. Origins and Evolution

Some of the origins of electricity and magnetism have already been covered in the Audio, Visual, and Radio Surveillance chapters and are not repeated here. You are encouraged to cross-reference the early discoveries that are described in these other chapters.

Thousands of years ago, the properties of highly magnetic materials were observed by the people of China and Greece. Magnetite, an oxide of iron, is a natural material that is known as *lodestone* when it comes out of the ground exhibiting natural magnetic properties. Magnetite can be readily magnetized. Magnetite was used in antiquity to make 'magic stones' and contributed to the invention of the early compasses.

The attractive properties of amber and glass, when rubbed with silk or cotton, respectively, have been known for a long time and the phenomenon is colloquially known as *static electricity*. For hundreds of years, however, it was not known if magnetism and static electricity were the same or different phenomena.

In 1600, William Gilbert (1544-1603), an English physicist and physician, published "De magnete" based on his studies of magnetism and its characteristics. He made important distinctions between the attractive properties of amber and those of lodestone, a natural magnet. He further established the idea of the Earth having a large magnetic field.

Benjamin Franklin (1706-1790), American statesman and scientist, introduced the concept of positive and negative charges based on his experiments with electricity. Franklin's experiments also suggested that *charge* is not something that is created at the point where materials are rubbed and 'electrified' but rather that a transfer of charge from one body to another is taking place.

The 1700s and 1800s - Progress in Understanding Magnetism

In a relatively short time, beginning in the second half of the 18th century, significant progress in our theoretical and experimental understanding of magnetism was made by a number of gifted European physicists and mathematicians.

John Michell (1724-1793), an English geologist and cleric, invented a device called a *torsion balance* which he used to study gravitational attraction. In the mid-1700s, he demonstrated that magnetic poles exert attractive and repulsive forces on one another. Furthermore, he described a mathematical relationship between these forces and the distance between the poles. After his death, the apparatus came into the hands of Henry Cavendish, who continued experimenting with the device.

Joseph Priestley (1733-1804), a British chemist, provided experimental confirmation, around 1766, of the law that the force between electric charges varies inversely with the square of the distance between the charges.

Charles Augustin de Coulomb (1736-1806), a French physicist and engineer, independently confirmed various aspects of electricity and magnetism that had been studied by Michell and Priestley, by experimentally establishing the nature of the force between charges. He also invented a *torsion balance* apparatus in 1777, consisting of a fine silver torsion wire suspended from the top of a tube, with a horizontal carrier with bodies of known electric charges at each end of the carrier suspended at the base of the wire. The whole thing was placed inside a protective housing to screen out outside influences, like wind. When the mechanism was displaced by the attractive/repulsive forces, the amount of deflection could be observed through the glass housing. An arrow indicated the degree of torsion on a fixed scale. De Coulomb used it to accurately measure the force exerted by electrical charges and detailed his findings in his 1785 memoirs to the French Academy of Sciences.

In 1819, Hans Christian Ørsted (1777-1851), a Danish physicist and educator, demonstrated to his students the effects of stimulating a magnetic needle with an electric current, an important milestone that aided in the understanding of the relationship between electricity and magnetism. A unit for magnetic intensity was named the *oersted* in his honor.

In 1820, André-Marie Ampère (1775-1836) was following up on the research of Ørsted, and trying to formulate a theory of electricity and magnetism that would bring together the two phenomena. He suggested that the electrical activities in atoms might be associated with magnetic fields. Ampère described electrodynamic forces in mathematical terms and his writings aided in the subsequent development of magnet-moving coil instruments. In describing the relationship between the direction of magnetic rotation and current, he devised the 'left-hand rule' or Ampère's rule, which was originally based on the concept of a swimmer turning his head left while swimming in the direction of 'the current.' Early scientists weren't actually sure whether the phenomenon had an inherently left or right orientation. Later, Fleming contributed the 'right-hand rule' or Fleming's Rule, which is the one commonly used today.

While Ørsted and Ampère were adding to our knowledge, Michael Faraday (1791-1867), an English chemist and physicist, was conducting important experiments in electricity and magnetism. He created the *Faraday magnet*, one of the earliest electromagnets and, in 1831, he made a historic entry in his journal linking electricity and magnetism. Faraday put his new found knowledge to practical use by creating a *dynamo*, which is essentially a pioneer version of the electrical generator that brought about the industrial revolution.

Now that some of the basic theory and mathematics related to magnetism were being established, inventors began applying the information to the development of new instruments. Wilhelm Eduard Weber (1804-1891), a German physicist and associate of Karl Gauss, invented the electrodynamometer and developed sensitive *magnetometers* to detect weak magnetic fields.

Pioneer Work in Magnetic Resonance

The early half of the 20th century saw a lot of advances in various detection, measurement, and imaging technologies. It was also a time when historic strides were made in theoretical and experimental physics.

Not long after the concepts of superconductivity were experimentally developed, Walther Meissner (1882-1974), a German physicist, and Robert Ochsenfeld discovered the *Meissner effect,* also called *diamagnetism*, in 1933, whereby a superconductor expelled a magnetic field when cooling was applied at the appropriate times. This opened up the possibility of magnetic 'levitation' which could be applied to technologies such as magnetic trains and magnetic bearings.

During the 1930s, display technologies began to improve as well, with cathode-ray tube (CRT) technologies leading to radar scopes, televisions and, eventually, computer monitors.

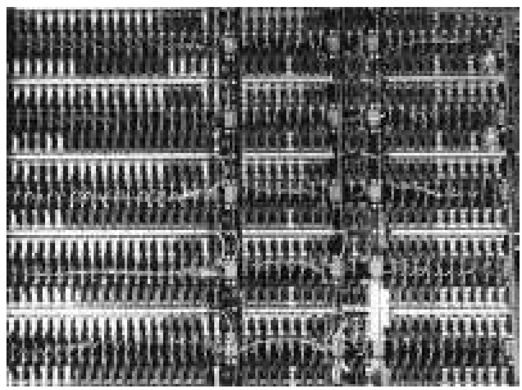
Some remarkable scientists set the scene at this time for future magnetic resonance imaging by describing the phenomenon of nuclear magnetic resonance (NMR).

Isidor Isaac Rabi (1889-1988), a Hungarian who immigrated to the United States at the age of three, became interested in atomic physics and was carrying out research on magnetic resonance based on molecular-ray models. By the late 1930s, Rabi had observed the absorption of radio frequencies by atomic nuclei and demonstrated the fundamentals of nuclear magnetic resonance (NMR). For his work, he received the Nobel Prize in physics in 1944.

In the mid-1940s, Felix Bloch (1905-1983) and Edward Mills Purcell (1912-1997) observed emission and absorption characteristics in nuclear magnetic phenomena and developed a nuclear induction method of measuring the magnetic fields of atomic nuclei. This was a remarkable achievement, considering the minute forces involved. For their work, they received a Nobel Prize in physics in 1952.

The Evolution of Electronics

The development of the computer was important to magnetic surveillance for two reasons. First, computing technology required memory to carry out the functions that inventors were dreaming up, leading to the evolution of magnetic memory, magnetic computer tapes, and magnetic discs. Second, the development of computer networks made it possible to process information stored on magnetic storage devices to develop sophisticated transaction, database, and surveillance systems.



Left: A magnetic core memory unit in a research laboratory in 1954 shows strides in the evolution of computers. Core memory provided important support to processing functions and later evolved into additional types of magnetic storage devices. Right: The inside of an IBM/UNIVAC computer, one of the first large-scale computer systems, at the Lawrence Livermore National Lab (LLNL). LLNL took delivery of the UNIVAC (Universal Automatic Computer) in 1952, a year after the Lab was founded. [NASA/GRC news photo by Walton; LLNL 1957 historical news photo, released.]

In 1947, the transistor was invented, which led to dramatic improvements in electronics, particularly in the areas of miniaturization and functional integration. However, it would take about a decade for transistor technology to become firmly established. In the meantime, vacuum-tube computers continued to evolve. The ENIAC and the UNIVAC weren't much more than advanced calculators, by current standards, but these advanced calculating capabilities were important, providing the basis for new discoveries in mathematics, physics, astronomy, engineering, and instrumentation. Within twenty years, full-scale software-programmable computing systems with magnetic memory and magnetic tape storage capabilities would become well established.

The development of *magnetic core memory* opened up a new world of computing capabilities. Core memory made it possible to develop reusable code, new programming languages, and compilers, innovations which had been impractical to implement or unreliable on the earliest systems. Magnetic memory also contributed to the later evolution of miniature magnetic strip cards.

New miniaturization and memory storage technologies were well underway by the 1950s. They didn't have an immediate commercial impact, because of the huge financial investments that had been made in the first room-sized computers, but by the 1960s, the microelectronics industry was beginning to reach new markets and the old systems rapidly became obsolete.

As soon as magnetic storage systems were established in the computer industry, inventors began to look for other ways to use magnetic media to store information. Magnetic stripe cards began to emerge in the early 1960s and were almost immediately put to use in transit system checkpoints. Some cards were read-only, in which the same information was read from the card each time. Others were read-write systems in which the data could be changed. This made it convenient to associate the data with a monetary value, such as a copy card or transit card, in which the value on the card, which was usually prepaid, would be reduced each time it was used.

It was not hardware alone that improved the state of the computer arts in the 1960s. Mathematics and software design were evolving as well. They not only provided steady improvements in the speed and efficiency of computer systems, but also greatly improved the process of creating magnetic resonance scan images. MRIs that took almost a day to scan could now be scanned in just a few hours. Eventually, scanning speeds would improve to less than an hour and by the year 2000, certain offshoots of magnetic imaging would be near-realtime.

Transaction Cards

Retailers have been extending credit to customers for hundreds of years. Corner grocery stores commonly carried small accounts for good customers until about the 1970s. By the 1920s, some companies were starting to create company charge cards that were engraved to protect them from forgery. These were the precursors to the charge and credit cards that emerged in the 1950s, the transit cards that were in use in the 1960s, and the automatic teller cards that became prevalent in the 1970s and 1980s.

Standardization of magnetic stripe cards began to be established in the early 1970s. Up to that time transit cards, for example, used proprietary data storage schemes. With the standardization of cards, broader use for other applications were possible and magnetic stripes became important for transactions associated with travel. By the 1980s, almost all transaction cards in western countries had a magnetic strip embedded into the surface.

By the mid-1980s, cards that could be used to access telephone service were being developed and by the 1990s 'phone cards' with prepaid long-distance access were commonly sold in retail stores.

Eventually the idea was extended to access cards and badges. By adding magnetic strips to employee cards, they could be designed to allow access to buildings or certain parts of buildings. Strips on conference badges could serve the same purpose or could be coded to allow access to the specific seminars for which the conference attendee had paid.

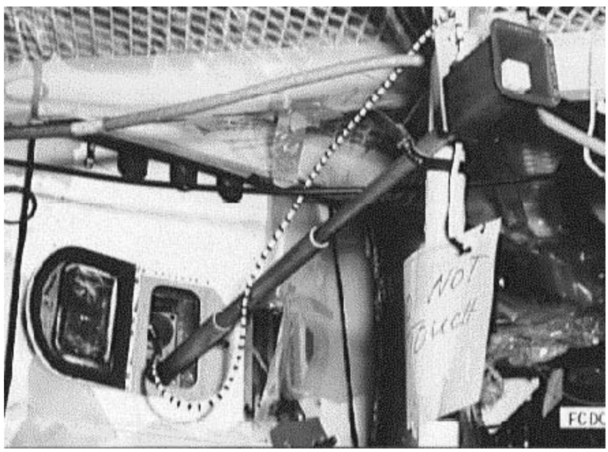
Smart Cards

The real key to the evolution of 'smart cards,' that contained small circuit boards, was the invention of transistors in 1947 and the microcomputer revolution in the 1970s. These key technologies led to ultra-tiny computers that were capable of processing information and which could draw their information from magnetic strips embedded in the cards. In 1974, the concept of the Smart Card was patented by Kunitaka Arimura and, in 1974, Roland Moreno also patented the idea. It was not long before companies saw the potential of this technology and began licensing it.

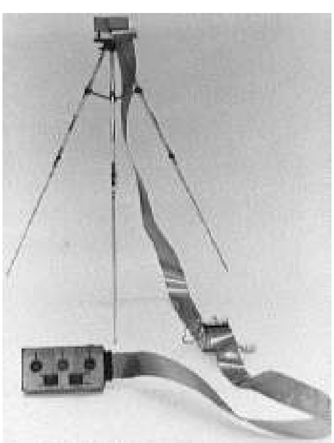
It was clear that widespread use of magnetic and computer cards was going to require some standardization, so that people could use their cards in a variety of locations when they were traveling. By the late 1980s, ISO standards for cards were being developed.

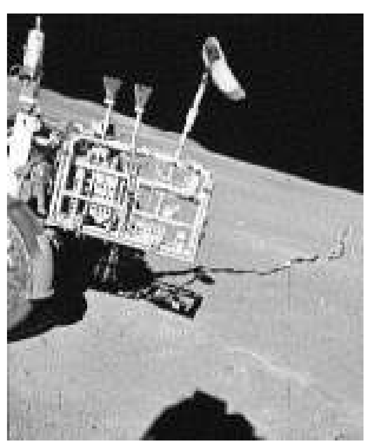
Space Science

Research and development in one industry often contribute to inventions in other industries. This has been true of many aspects of the space program. Space is a difficult environment in which to live and work and large amounts of radiation that don't reach Earth's surface are prevalent in space. In order to put vehicles, sensing instruments, and people into space, new materials that could deflect heat and radiation, new protection gels, fine instrumentation, and a large variety of sensors were developed. The polymers and devices originally invented for space or extraplanetary exploration were later used to develop systems that have been useful in industrial and medical environments.



Shown here are the sensors and boom from the *tri-axis magnetometer* carried on board the Gemini 12 space flight in 1966. [NASA/JSC 1966 historic news photo, released.]





Left: This is a portable magnetometer designed to be used by the Apollo 14 crew to measure variations in the Moon's magnetic field at several different points. The device mounted on the tripod is a flux-gate magnetometer sensor head connected with a 50-foot flat ribbon cable that interfaces with an electronic data package. Right: A Lunar Portable Magnetometer (LPM) mounted on the Lunar Roving Vehicle on the Apollo 16 mission. [NASA/JSC 1970 and 1972 news photos, released.]

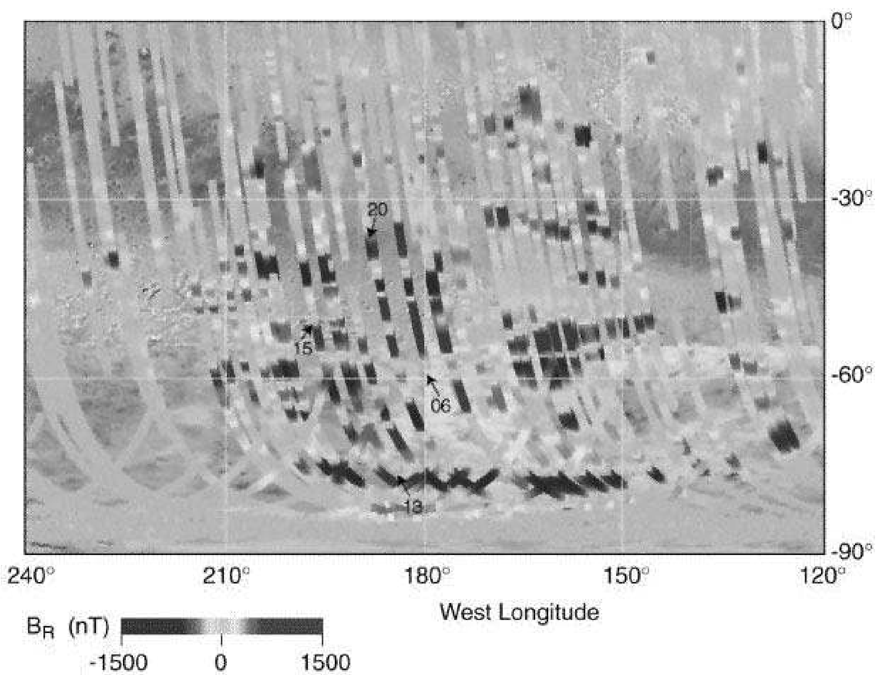
In 1966, the Gemini 12 space project included a *tri-axis magnetometer* (MSC-3) which was designed to monitor the direction and amplitude of the Earth's magnetic field relative to the spacecraft. Room on a space flight is very limited, so the instrument had to be designed to be light, portable, and to consume minimal power. It also had to be more sensitive than Earth-based magnetometers, since the magnetic forces on the Moon are only a fraction of those found on Earth.

Several Apollo space missions to the moon took measurements of the Moon's magnetic field using a Lunar Surface Magnetometer that was part of the ALSEP experimental package. The Moon's magnetic field is influenced not just by the Moon itself but also by external sources such as the Sun and the Earth. By taking a series of measurements over the time it takes the Moon to move through its orbits, it is possible to better distinguish the Moon's field from the external forces.

In August 1999, work was beginning on a magnetometer (MAG) calibration sequence which would be used on the Mars Global Surveyor spacecraft to help characterize the Surveyor's magnetic signature and to execute a series of solar array motions on the dark side (night side) of the orbit.

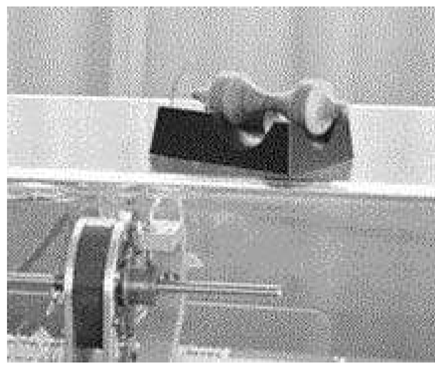
Magnetometers

Magnetometers are specialized instruments used for magnetic detection and imaging.



A magnetic map created with data from a magnetometer. In this case, it is a map of a portion of Mars, near the Terra Cimmeria and Terra Sirenum regions. The pattern of the stripes is quite similar to patterns of magnetic mapping of the Earth's crust at the mid-oceanic ridges, indicating that the crust may have shifted in much the same way as the Earth's and that Mars may once have had a more global magnetic pattern similar to what Earth has now. [NASA March 1999 news photo, released.]

Early magnetometers were bulky, which limited their use for field work or commercial surveillance. By the 1960s, the space program began to contribute to the science of portable, compact magnetometers. By the 1980s, miniaturization and improvements in electronics were making it possible to develop more efficient, smaller systems, a trend which continued into the 1990s. By the mid-1990s, many magnetometers included data link capabilities so computers could be used to display results or to log activities. Thus, systems that needed to be smaller and lower in power consumption, such as demining magnetometers, magnetometric buoys, portable geoscience sensors, and commercial sensors, could now be constructed.



This magnetic suspension demonstration was part of the EAA AirVenture '99 exhibit in Wisconsin. If you look closely, you can see that the small object on the top of the cabinet on the right is suspended magnetically in the air without physical contact with the device underneath it. [NASA/Langley Research Center news photo by Donna Bushman, released.]

In 1996, UNICEF reported that there were about 110 million land mines distributed throughout more than sixty countries, many of them activated during conflicts that had long since been settled. These mines are often unintentionally triggered by vehicles, animals, and children's playtoys, blowing off limbs and sometimes causing death to innocent victims. Magnetic sensors are one of the means by which mine-detection systems help to locate live mines.

Magnetic Tags

With increasing miniaturization, it became possible to create small-scale, cost-effective magnetic sensing instruments that could be used for inventory management, theft-deterrence, and wildlife-tracking. Libraries installed the systems to protect against book theft, with the practice becoming commonplace by the late 1980s. Retail stores began to adopt the systems for higher-priced items in the late 1980s and early 1990s and for smaller, easily shoplifted items like portable electronics and music CDs by the mid-1990s. Also, in the mid-1990s, magnetic systems for tracking wildlife were becoming practical. In conjunction with GPS technology and depth-recorders, tri-axial magnetometers were being used to track the movements and behaviors of marine mammals such as seals and whales.

Data Cards

By the 1990s, casinos, hotels, clubs, rental depots and other types of businesses that catered to a large segment of the public began using magnetic cards and keys that would allow them to store and analyze the information provided when clients used the cards in various gambling and vending machines and in doors and vehicles. Soon universities and office complexes were installing magnetic locks and card readers as access control devices. Student cards could be designed so they not only opened doors, but could be used in vending machines, as well. By the end of the decade, the hardware to install these systems and the database software to track and log the activities of cardholders had become quite sophisticated.

5. Description and Functions

Measures of Magnetic Field Strength

Some sensors measure the presence or absence of a magnetic field, some measure relative changes in a magnetic field over time, some measure the strength of a field in relation to other nearby objects, and some measure it on a standardized scale.

A *magnetometer* is a device that measures the strength of magnets and magnetic fields. It may also ascertain the direction and origin of the field in relation to the measuring device. A magnetometer is called a *Gaussmeter* in honor of Johann Karl Friedrich Gauss (1777-1855), a German mathematician and astronomer who investigated magnetism in conjunction with W. Weber in 1831.

Several different unit systems are used to express the strength of a magnetic field and different aspects of magnetic flux density, so the conversions can be somewhat technical. This list is simplified to give an introductory idea of the types of units that are used:

gauss (G, Gs) - The Earth's magnetic field is about .25 to .5 gauss. Gauss tends to be used to measure magnetic flux density and magnetic induction (B). One gauss corresponds to 10^{-4} tesla.

gamma (λ) - One gamma corresponds to 10^{-9} tesla. This unit is useful in situations where very weak magnetic fields are being measured, as might be found on asteroids or moons. It is often used to express quantities in magnetic survey maps.

tesla (T) - This unit tends to be used to measure magnetic flux density and magnetic induction. A tesla corresponds to 10^4 gauss. The tesla unit is named after the physicist and inventor Nikola Tesla.

There are other units, including webers (W), ørsteds (Oe), and maxwells, that are applied to various aspects of magnetism. The *Resources* section at the end of this chapter lists online resources with tables of different magnetic measures and conversions.

A *geomagnetic field* is the overall magnetic field of a planet's or satellite's surface. It is comprised of the celestial body's internal field together with the magnetic fields within its atmosphere (if there is one). For reference, the Earth's magnetic field is around 300,000 gammas. In the Apollo space missions, the Moon's magnetic field was measured with sensitive lunar surface instruments and found to vary from about 6 gammas to about 313 gammas, depending on where and when the measurements were taken.

Magnetic sensing may at times be combined with electrical assessments in a *resistivity survey*, which measures the relative differences in the electrical resistivity in materials such as soil. It may also be used in conjunction with ground-penetrating radar, a means of using radio waves to assess the relative densities of a stretch of ground or water, and seismic sensors, which measure pressure waves conducted through materials.

Magnetic Cards

Access and transaction cards are described here, while smart cards with processing capabilities are covered further in the Computer Surveillance chapter.

Access/transaction cards tend to come in three basic types:

proximity cards - These are cards that do not need to touch the sensor. Proximity cards are generally the simplest type of card and are usually used in situations where information is not needed. A proximity card is like a trip-switch. It can trigger a sensor so that a circuit can be turned off or a door or cash mechanism opened or closed. One of the advantages of proximity cards is that the contact surface does not readily get scratched or worn.

contact cards - These are cards that are held against a surface to be sensed or scanned. For some types of contact cards, the position of contact is standardized. They are usually used in access systems and typically do not convey much information, if any. They are similar to proximity cards.

swipe cards - These are cards which are either 'swiped' or pulled through a reader, or which are placed in a reader that has a built-in scanning 'swipe' mechanism to read and/or write data on the card. Swipe strips are commonly included on ATM cards, credit cards, and employee cards. There may be a significant amount of information stored on a swipe card, including account information, name and address, time, date, logging information, etc.

ID card printing machines may use a Magnetic Stripe Encoding Module (MSEM). Many of these card printing systems conform to ANSI/ISO standards. Magnetic encoders for standard cards fall into two general categories, so it is important to select the right type of card to match the encoding scheme. The two common categories are

low coercitivity - These data systems are common on transaction cards and are often brown in color. This is a less expensive type of encoding and is suitable for low to medium-high usage cards.

high coercitivity - These data systems are more commonly used for higher-security applications and may be black in color. This type of encoding may cost a little more, but it is generally more robust.

Most card readers are designed to read both types of cards.

The chief limitations of all magnetic cards are the potential for loss or theft and the potential for the magnetic data to be disturbed by proximity to other magnetic sources such as other magnetic cards (never carry them with the strips facing one another), magnets, computer monitors, or strong electrical sources.

EAS

Electronic Access Systems are those which use electronic or magnetic detection systems to sense or control in-and-out traffic to restricted areas. Many of them are more specificially *Electronic Exit Monitoring* (EEM) systems that are used widely in libraries and retail stores where managers are more concerned about monitoring what people take out than what they bring in. Most people in the industry use EAS as an abbreviation for the more generic phrase *Electronic Article Surveillance* to describe the process of tagging individual articles for tracking or entry/exit monitoring.

For the purposes of this text, *Electronic Access Surveillance* is used to mean the use of electronic cards, keys, or door/window sensors to track or detect entry and/or exit. *Electronic Article Surveillance* is used to mean articles that have magnetic sensors attached or incorporated into their design that are subsequently detected or tracked through compatible sensors. There is sometimes overlap between these systems.

Libraries are big users of Electronic Article Surveillance (EAS). The theft of books by professors and students is apparently quite prevalent. Many libraries have rare or expensive books that are difficult or impossible to replace. Article surveillance helps cut down theft and the cost of replacing stolen materials.

Retail stores now commonly have electronic and magnetic sensors in their doorways or in other areas where there are articles that are vulnerable to theft. These vary in design and in the technologies that are used, but many of them are like the electronic gates in libraries that sense magnetic disturbances and signal an alert or alarm when an active magnetic source is encountered.

There are two common types of tagging systems:

tags that can be attached/removed - Removable tags are commonly used for more expensive items. Most of them remain activated all the time so that if an item is taken through a checkpoint, the alarm is sounded. If an article with the tag is purchased or legitimately removed, the tag itself is removed so that it doesn't trigger the checkpoint sensing device. These tags tend to be larger, palm-sized devices.

tags that can be activated/deactivated - Configurable tags are commonly embedded in an article or attached with a strip or sticker. These can be activated or deactivated as needed, usually by 'swiping' them through a source of magnetism/electricity. The checkpoint sensing device is usually set to sound an alarm if it senses an activated tag. These tags can be very small and may be hidden inside the item, or embedded in its design to prevent the patron from tampering with the security mechanism. Small security strips are sometimes called 'tattle tapes.'

Typically, products embedded with a magnetic device are 'swiped' to deactivate the sensor. Other 'high-ticket' items such as fur coats and diamond jewelry may have a larger, physical security tag which has to be taken off before the customer can go through the exit without triggering an alarm. Radio frequency technologies are sometimes used in conjunction with magnetic fields to track removable-tag systems. The alarm is not necessarily heard by the customer or client. It may sound in a security area from which detectives or other personnel are dispatched to apprehend the person stealing or moving objects without proper authorization.

Types of EAS Systems

Not all access/article surveillance systems are based directly on magnetic devices, some use radio signals or acoustic signals, and many use a combination of these technologies. However, keep in mind that electricity and magnetism always occur together. Thus, access systems that rely on the generation of an electric current will always have an associated magnetic field, and many security systems rely indirectly on magnetic forces even if physical magnets are not present in the system.

The type of sensor and the sensitivity of the sensor will dictate how far apart the sensors can be spaced in an entrance or exit checkpoint system. Low-sensitivity sensors may require more than one 'gate' as are sometimes seen at wide entranceways in retail stores in shopping malls.

Most EAS systems work on the same general principles. One of the gates is a transmitter, one is a receiver, and the tag is sensitive to the emissions specific to the transmitter. Gates for wide entrances are sometimes paired or combined, but the principles are the same. The receiver expects to receive a certain signal to indicate a deactivated or activated tag, depending on the system. Three common EAS schemes used in retail and library systems are

Acousto-magnetic systems are three-part active systems that consist of a transmitter, a receiver, and security tags. They work by transmitting a radio frequency pulse. When someone walks through the checkpoint, this pulse is received by a security tag, which responds with a single-frequency pulse as the transmitting pulse ends (so the signals don't clobber one another), which is then detected by the receiver. If the received pulse matches the frequency and timing characteristics expected (or doesn't match it, depending on the system), an alert is sounded.

Electromagnetic systems are three-part active systems that consist of a transmitter, a receiver, and security tags. The transmitter transmits a continuously varying field between the transmitter and receiver. Since there are always magnetic fields associated with electrical fields, a magnetic field is created between the transmitter and receiver with a shifting polarity. The strength of the field also varies. The magnetic field influences the field of a tag, as a person walks through the checkpoint, generating a signal that can be checked against the transmitter signal. If the received signal from the tag matches the harmonics and strength expected by the receiver from an active tag, an alert is sounded.

Microwave systems are three-part active systems that consist of a transmitter, a detector, and transceiving security tags. The transmitter generates modulated signals, usually over two frequency ranges. The signal interacts with the tag, which is a small palm-sized microwave transceiver, and the tag processes the signal, emitting its own characteristic signal when someone walks through the checkpoint. If the signal received by the detector is a specific frequency, indicating an non-deactivated tag, an alert is sounded.

It is estimated that at the present time there are close to one million EAS systems installed around the world.

Magnetic Surveying

A magnetic survey is a technique for getting reference measurements of the Earth's magnetic field so that other magnetic structures that are being sought in a region can be distinguished from the background magnetism. A *proton magnetometer* may be used for this task.

Many human-made objects are fairly highly magnetic in relation to soil, water, plants, and other materials that might be present at a site that is being surveilled. Appliances, coffin hardware, ships, vehicles, jewelry, kiln-heated bricks and pottery, all have measurable magnetic properties that can be detected with appropriate tools. This makes magnetic surveys valuable for forensics, mine detection, and archaeological exploration, as well as earth sciences research.

6. Applications

Access Monitoring and Data Tracking

The use of cards with magnetic strips to access automatic teller/transaction machines (ATMs) is probably one of the most familiar uses of magnetic detection and data management. The same principles are used in credit cards, phone cards, and cards designed for vending machines. Similar systems can also be used for doors and restricted access areas in labs, industrial facilities, and offices. When linked to a computer database, more sophisticated data can be stored and processed, including frequency of use, times used, locations, etc.

Left: Point-of-purchase machines now commonly accept debit and credit cards with magnetic 'stripes' for transactions at numerous locations including banks, gas stations, supermarkets, and department stores. Middle: Cards generally fall into two categories: low coercitivity (top) and high coercitivity (middle and bottom), depending on the level of security desired. These are sometimes distinguished by brown or black magnetic surfaces. Right: Magnetic cards and keys are also used to open doors to buildings, offices, hotel rooms, and other restricted access areas. [Classic Concepts ©2000 photos, used with permission.]

Archaeology

In archaeology, magnetic detection is used along with resistivity surveys, and pulse radar surveys, to assess research locations and to explore data from surveys. *Archaeomagnetic dating* is a technique based on assessing the variation of the Earth's magnetic field as it changes through time. The Earth, as it spins, has a rotational wobble that repeats over a long period of time. Knowledge of this variation can help assess many types of artifacts such as historic kilns and other metallic and metal-smelting structures.

Detection of Land Mines and Bomblets

By the mid-1990s, it was estimated that more than 100 million active land mines were spread around the world. In addition to this, the U.S. forces dropped millions of 'bomblets' over the Laotian region during the conflicts in Vietnam, not all of which exploded on impact.

The detection and neutralization of land mines and bomblets is a continuing problem. Since many technologies are used to detect mines, it has also been mentioned in other chapters. Mine-detection is a process that involves determining a suspect region, finding individual mines, and dealing with the mines once they have been detected.

Demining can be especially challenging if it has to be done in forests or swampy areas, where there are many obstacles, objects, or conductive surfaces to interfere with demining equipment or detection devices. Magnetic detection is one of the technologies that has aided in this process. When added to the arsenal of probing sticks, bulldozers, ground-penetrating radars, sniffing dogs, and electronic sniffers, it provides one more tool to protect innocent civilians and armed service personnel from disfigurement or death.

One demining device of interest is the Meandering Winding Magnetometer (MWM) that was devised at MIT by James R. Melcher and his colleagues. The device makes it possible to sense the approximate size, shape, depth, and sometimes even the composition, of a buried metal object. MIT currently sponsors the Humanitarian Demining Project which has received funding by the U.S. Department of Defense.

Detection of Submarines

Ships and submarines alter the magnetic fields of the water in which they are located. Submarine-sensing magnetometers can be designed to indicate the presence of surface or submerged vessels. Using a magnetic submarine sensor from a ship or another sub would be difficult, since the interference from the deploying vessel would obscure the readings from other vessels. However, it is practical to consider the use of submarine sensors from helicopters and autonomous or remotely operated aerial vehicles. A magnetometer can be attached to a 'boom' in much the same way as a sonar towfish is used to troll waters looking for submerged vessels. It is not uncommon for sonar and a marine magnetometer to be used together. It can also be attached to a buoy and might be further equipped with radio transmitting capabilities to send readings to a satellite relay or nearby vessel.

Electronic Article Surveillance

Electronic security devices to track vehicles, books, and retail goods are now common.

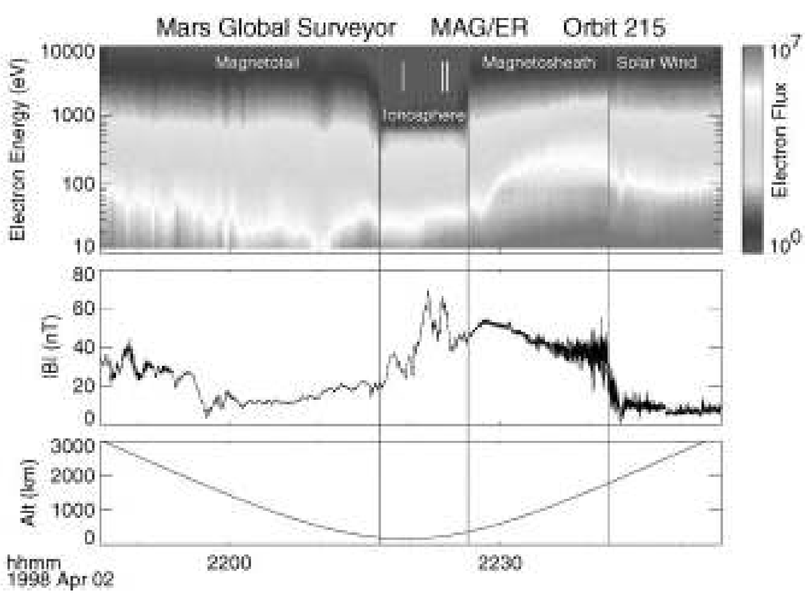
These photos show four slightly different electronic article surveillance systems that are commonly used in the retail industry to prevent theft of clothing, jewelry, music CDs, and computer games. As the articles are paid for at the cash registers, the attached sensors are removed or deactivated so they don't trigger the exit systems when the customer leaves with paid items. Most systems consist of a transmitting 'gate' and a receiving 'gate.' Each retail outlet shown here also has visual surveillance camera systems installed inside the store. [Classic Concepts ©2000 photos, used with permission.]

Libraries and retail stores are the biggest users of electronic article security systems. By attaching a magnetic strip, 'tattle tape,' button, film or other object that can be programmed or activated/deactivated, it is possible to detect the presence of an object and, in some cases, even its location and velocity. Most retail outlets use a combination of acoustic, magnetic, and electromagnetic (radio frequency) emissions to reduce the incidence of theft. 'Gates' in entranceways typically incorporate transmitters and receivers that sense security tags that are attached to items or embedded in the items at the time of manufacture.

Geophysical Sciences and Site Surveys

Magnetometers are used in hundreds of types of research and sensing projects, but are especially valuable for studying the Earth and its various geophysical structures. The Earth itself has an overall magnetic field that we can detect with a compass and some regions have mineral deposits with sufficent magnetism to interfere with the normal use of a compass. *Magnetic susceptibility* instruments aid in studying rocks and sediments. They have also been used to assess the magnetic characteristics of other bodies in our solar system, including the Moon, Mars, and Io, a moon of the planet Jupiter.

NASA and other organizations have developed quite a number of magnetometer devices, and there have been spinoffs of this science in other areas, including magnetic resonance imaging (MRI) which is used extensively in the medical field. Johns Hopkins has been active in the development of space-related magnetometers, including a high-sensitivity, wide-dynamic-range sensor called a *xylophone bar magnetometer*.

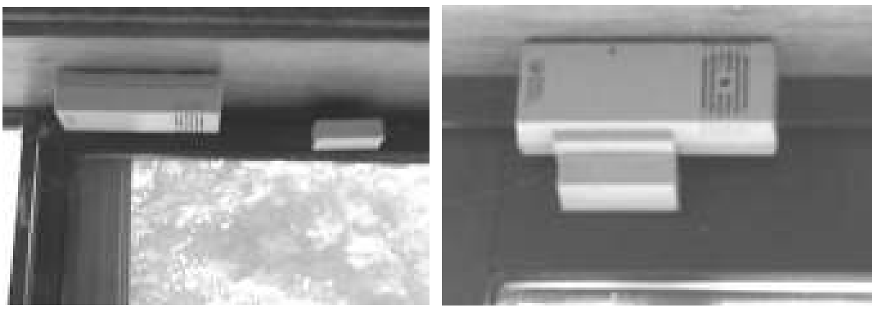


A chart of magnetic measurements taken as the Mars Global Surveyor spacecraft passed from the solar wind regime through the magnetic regimes of the planet Mars. [NASA June 1999 news diagram, released.]

Fluxgate magnetometers can be used to survey a site prior to installing sensitive magnetic equipment as might be used in a research lab or medical facility. They can also be used to provide reference data for Earth mapping projects and observatories.

Home, Business, and Vehicle Security

Magnetic strips, tapes, buttons, keys, and reed switches are all used to provide various degrees of security to homes, offices, retail products, library books, and vehicles. Most of these are two-piece systems that consist of a strip or card that generates a magnetic field or which holds magnetic data and a sensing system that detects (or fails to detect) the magnetic field or reads the magnetic data.



Two-piece sensors that are activated by the motion of a magnet breaking the contact or moving past the contact are common in home and office security systems. Since most of them are small and wireless (battery-operated), they can easily be placed on doors, windows, closets, and lids. Many of them use radio frequencies to send the alert to a central console that can be configured to sound an alarm. These Black & Decker magnetic components are common in homes and offices. [Class Concepts ©1999, used with permission.]

This looks like a conventional lock and key, but the key is magnetic (note the three dark indented strips), and the lock has an electronic storage capability for logging the times and dates when the lock is used, along with who has been accessing the door. To read the data, a portable computer, equipped with a cable that attaches to a data-reading key, is hooked into the locking mechanism. The data are then downloaded to the computer for analysis and storage. If a key is used inappropriately or there is some question about the user, the lock can be reprogrammed to reject access the next time the key is used. In more sophisticated systems, an alert can be sounded, or a video camera activated if someone questionable tries to gain unauthorized access. [Class Concepts ©1999, used with permission.]

When magnetic systems are used for exit monitoring, they are sometimes combined with other technologies, including radio-frequency signals or acoustic signals.

Shock Wave Detection and Research

The detection of shock waves is important for an understanding of geosciences, but it can also be a life-saving measure. Shock waves from tidal waves, nuclear or chemical explosions, volcanic eruptions, land slides, avalanches, or other significant events can often signal trouble before the trouble arrives. Shock wave laboratories use a variety of technologies to study and classify shock waves. Light gas guns are one of the devices used to launch projectiles at high speeds in order to generate and study impact craters and shock waves. These guns can use magnetic detection to measure the velocity of the projectile so the data can be cross-referenced with results from other tests.

Traffic Assessment

Magnetic sensors have been used in many types of traffic assessment. Depending on their type and placement, they can be used to assess the presence, volume, and speed of cars and trains, and have been established in a fairly extensive network in the San Francisco Bay area, for example.

Intelligent Vehicle Systems, those which incorporate vehicles that can essentially drive themselves have been designed in a number of ways, but some use magnetic sensors to assess the location and proximity of vehicles to certain locations and to each other in order to automatically manage the traffic. Potentially, the information on a specific vehicle and its occupants would be put into a database to assess route preferences, speed preferences, schedules, priorities, etc. While this might be convenient and of interest to some, others might be concerned about the privacy issues inherent in this type of system.

Underwater Surveillance

Many of the structures and objects that are sought underwater have strong magnetic fields that lend themselves to detection with various magnetic devices. Towed magnetometers and diving magnetometers are available for salvage and search and rescue operations. These systems are often interfaced to computer systems for analysis and display. Deep-tow and shallow-tow systems are usually sold as separate items as the deep-tow devices (e.g., 2,000 meters or more) require special shielding to protect them from the high pressures that exist at great depths. Some marine magnetometers can also be used for certain land-based operations.

7. Problems and Limitations

The most significant problems with magnetic sensing devices are background interference from other magnetic sources such as the Earth, false alarms triggered by magnetic items other than those being monitored, and the loss or theft of items containing information that is stored magnetically. There are also limitations associated with the amount of time it takes to read and interpret data in highly sensitive magnetic arrays with many elements. Finally, there are always problems with improper maintenance of machines or use by insufficiently trained personnel.

Magnetic Interference

Background interference can be overcome to some extent by carrying out a 'survey' of an area, that is, a series of readings, sometimes over an extended period of time, that provide references from which to interpret the data of interest. Shielding is another way in which background interference can be reduced. Highly sensitive machines such as magnetic resonance imaging (MRI) machines are heavily shielded to screen out the Earth's magnetic interference, as well as interference from other building structures and appliances.

Databases of the magnetic properties of various types of materials can aid in reducing false alarms and in identifying specific types of objects, as in archaeological and forensic surveys.

One interesting source of cosmic magnetic interference is a newly discovered celestial body called a *magnetar*. A magnetar, once considered only theoretical, is a rapidly spinning core that remains after a supernova. The magnetar generates an enormous magnetic field, discharging huge amounts of charged particles that can affect other celestial bodies for quite a distance. Just as Sun spots can disrupt radio communications on our planet, discharges from magnetars can interfere with sensitive orbiting communications satellites.

False Alarms

False alarms are common in magnetic sensing systems. Many objects other than special tags, or the object being sought, can trigger a magnetic sensor.

False alarms are usually handled either by seeking out the items that are triggering the alarm (as in airport, library, or retail security systems) or by using several different types of sensors and making a determination on the basis of multiple inputs.

Theft and Tampering

There are two aspects of using magnetic tags and tapes for electronic article surveillance that are somewhat difficult to overcome:

- Removal of the magnetic strip tag prior to shoplifting an item, enabling a thief to pass through a sensor checkpoint undetected. Manufacturers have tried to minimize this problem by embedding the tag in the product or hiding it underneath the visible layers of a product in a process called *source tagging*. Source tagging also saves the retailer time, as it is not necessary to individually tag items before placing them on the shelves.
- Deactivation of the tag could allow it to be shoplifted unseen or taken out of a library without being properly checked out.

Fortunately, these types of theft and tampering take extra effort and equipment, and hence are less frequent. As magnetic films, inks, and papers are devised, it becomes more difficult for people to defeat the security systems.

Detection Speed and Processing

Speed (or the lack of it) is a limitation and an important aspect of magnetic detection in a number of technologies.

- Towed magnetometers, as are used from aircraft or boats, need to be able to resolve and store or transmit the data at whatever speed the host vessel is traveling.
- Intelligent vehicle transportation systems need to be able to respond to inputs at the speed of traffic and may need to be able to recognize individual events or vehicles.
- Magnetic resonance imaging systems need to be able to scan as quickly as possible without loss of data for the sake of the comfort of the person being scanned and for economic reasons related to the cost of operating the equipment. Improvements in both software algorithms and hardware have greatly decreased the time it takes to do a scan from many hours to several hours to less than an hour, so the technology has greatly improved over the last two decades. Some adaptations of MRI technology now operate in near-realtime.

8. Restrictions and Regulations

Transaction Cards

Cards with magnetic stripes for local use can be custom-designed with proprietary data formats, but if the cards are to be used in standardized card writers and readers or on Internet-based computer systems, they must conform to certain standards in order to ensure compatibility. Various standards organizations have established data standards for transactions cards with ANSI/ISO standards being prevalent.

The use of cards for electronic transactions and fees associated with their use are regulated by such acts as the Electronic Fund Transfer Act and the ATM Fee Reform Act of 1999. These types of acts not only regulate the amount and frequency of fee assignments, but also contain stipulations about notifying the customer in various ways, such as on an ATM display screen or on the account printout associated with a transaction.

Electromagnetic and Magnetic Interference

Some electronic article surveillance systems are hybrid systems that use more than one type of technology. Radio-frequency sensors and magnetic sensors are often combined, thus creating a potential for both magnetic and radio emissions that might influence the surrounding environment.

Because magnetic and electromagnetic fields can interfere with the operation of nearby devices, there are some regulations for electronic article systems (EASs) which limit the magnetic field strength and detection sensitivity of the tags, the sensors, and transmitters. A clothes rack full of articles that have magnetic tags could potentially affect customers with small electronic devices and there have been reports that certain EAS checkpoint sensors may interfere with medical pacemakers and other bionic medical devices.

Some EAS systems are passive detectors that light up or sound a local alarm. These are not likely to cause problems with pacemakers. However, active sensing systems and those which generate radio frequencies may cause problems, particularly those in the microwave wavelengths. Some stores have signs warning pacemaker users that the security system may have an affect on their pacemakers. In some areas, these signs are required.

In the United States, the Federal Communications Commission (FCC) is the primary agency regulating emissions standards. Those with an interest in manufacturing or selling EAS systems have petitioned the FCC to increase maximum allowable standards, but these requests have usually been denied.

See also the Restrictions and Regulations section in the Computer Surveillance chapter, since some of these apply to computerized ‘smart card’ surveillance technologies.

9. Implications of Use

Most aspects of magnetic sensing are subject to a minimum of controversy. Magnetometers that are used in geosciences, search and salvage, and medical applications generally contribute to our knowledge and quality of life. Some can even save lives. Magnetic strips that are used to protect inventory in stores and libraries are not often challenged or questioned, since the owners have a right to protect their investment and magnetic monitoring is far less obtrusive than many other methods.

However, there are a few aspects of magnetic sensor use that are likely to become controversial, mainly because they can link with computer processing techniques to create extensive and targeted databases.

Magnetic Cards - Use and Abuse

The most common problem with the use of magnetically coded cards is that they can be lost or stolen. It is inconvenient and problematic to replace ID and credit cards, and fees associated with cards go up when the incidence of theft and unauthorized use rises.

Since most card swipe machines are now standardized, it is not difficult for thieves to acquire the machines (or access to the machines in their places of work) and to write their own cards or to read information off the cards that might help them locate your house, your job, your bank account, or your magnetic-access home safe.

Some vendors have proposed using biometric identification systems along with the cards in order to reduce the incidence of theft and unauthorized use.

Electronic Article Surveillance

Magnetic strips in clothing, library books, and other retail or loan properties are now common. The surveillance checkpoints at the entrances of retail stores are usually based on magnetic or radio-frequency surveillance technologies. Magnetic gates in most stores work with *dumb tags*, that is, magnetizable tags that are either activated or deactivated. However, a number of inventors have been working on *smart tags* which can be coded or assigned with group signatures or unique signatures (or both). This has obvious benefits for retailers, as it can potentially be used to aid in the management and automation of inventory. But it may spell trouble for consumer privacy. Consider this potential scenario:

> A retailer attaches smart tags to all the items in a retail store in a mall. The store is equipped with magnetic exit monitors that can read the smart tags. Since most systems are standardized so they can be sold to thousands of retailers, other stores in the mall have installed compatible smart tag systems. The smart tag has two types of information, the on/off system that tells whether the consumer has paid for the item and an inventory system. The store also has a video surveillance camera and a computer database. A customer enters the store, purchases a number of products, has them deactivated by the cashier and pays for the purchase. The inventory information on the card is not deactivated and is entered in the computer database. The customer now heads for the exit and, as she or he passes through the checkpoint, the video image is triggered to snap a still shot of the person's face and add it to the database, along with a record of the items carried out by the consumer, which include not only the purchases just made (which can be distinguished by the computer), but the purchases made in all the other stores. The whole thing is automatically processed and the retailer can now read data on the computer screen that shows pictures, the patrons' names (since most people pay with checks or credit cards), the date and time of past and present purchases, and items purchased in other establishments. Over time, the vendor builds a picture of what the person buys, how often the person shops, and the total value of the goods purchased, developing a psychological profile.

The technology to carry out this type of surveillance *profiling* already exists. The only real hindrance at the moment is designing checkpoints that can read the data fast enough, as the patron passes through the gates. It may be possible to produce this type of system within two or three years.

There has already been a court case in which a store tried to use the information in a shopping database to discredit a shopper. The customer had slipped on a spill in a supermarket and decided to sue the establishment for his injuries. The supermarket looked up his shopping record in their database and argued that it showed that he frequently bought liquor, implying that he may have slipped because he was intoxicated. In this case, the court didn't admit the shopping record evidence, but it shows how quickly the retailer attempted to use personal data to protect its business interests, regardless of the rights of privacy of the consumer.

There are currently no safeguards to protect consumers from being monitored and manipulated based on their shopping profiles. Advertisers are already using supermarket 'member' cards to print out ads on cash register tapes that are targeted toward the buying habits of individual shoppers. The same concept can be used by a retailer to flash a targeted commercial at a consumer as he walks out the door.

Consumer protection organizations in the 1970s were concerned about the potential for abuse from 'subliminal advertising.' But now we have the potential for far greater abuse from overt advertising targeted to specific people, especially young or technologically naive shoppers who aren't aware that they are being manipulated.

Personal Information and Magnetic Profiling

The increasing practice of issuing readable and/or writable magnetic cards and keys that are registered to a particular person or organization and which can be tracked through a databank or computer network extends to other types of businesses besides retail stores. Some organizations are building substantial data profiles on individual customers.

Casinos, hotels, and some trade shows now issue magnetic gambling cards, keys, or access cards to their clients. They typically request the person's name, address, and even personal interests before issuing the card. Each time the card is used, the information about the transaction is transmitted through a data network and entered in the firm's central database.

It doesn't take long for a gaming establishment, for example, to develop detailed economic and psychological profiles of individuals. Instead of using coins, clients purchase 'game time' on magnetic rewritable cards. It's convenient. They don't have to carry around heavy coins or constantly plug the machines. The gaming machines are networked to a central computer database. The data are processed to reveal how often people gamble, how much they gamble, what machines they prefer, their gender, names, addresses, and sometimes more. Since software is easy to enhance and modify, there's no reason why the information couldn't be cross-referenced to data on relatives or friends. The gaming establishment, trade show, or hotel knows where clients come from, what vehicles they drive, and what facilities they use within the premises.

There are honest businesses and there are dishonest businesses. The small percentage of dishonest employers and business owners now have the technological tools to determine where a patron lives and whether he or she is poor or wealthy, young or old, and married or single. Any employee with access to the database also knows that the patron is not at home while using the local services. This could be a recipe for disaster.

Honest hotel owners and casinos will assert that they have no intention of using the information for anything other than the comfort of the patron while gambling. In some cases this will be true. However, there are no social or legal guarantees, at the present time, to prevent them from providing the information to closely allied business contractors, marketers, mail-order sellers, and others. Just as catalog companies sell their mailing lists to generate additional revenue, retailers and casino owners may sell the mailing lists and profiles to other firms to generate additional revenue.

The Monitoring of Employees

A further cause for concern is the fact that even an honest business does not have absolute control over the actions of all its employees. When data obtained from magnetic access cards are fed into computers alongside images from video cameras, an employee who might be a potential thief, killer, or stalker, unknown to the employer, has a great deal of sensitive information that could enable him or her to find and harm an innocent victim. A now famous case from 1989 involved two Swiss banking employees who were offered a large sum for aiding foreign tax authorities in decoding magnetic tape contained in the bank customers' data. Thus, it has already been demonstrated that people we generally trust, such as government officials and employees of banking institutions, have been known to abuse sensitive information for profit or political gain. There are also numerous documented cases of programmers leaving an employer and taking all the computer data with them to start new companies, without the employer being aware that data have been stolen.

In order to build up the confidence of their patrons, casinos and hotel owners using client databases will have to set up stringent safeguards to protect privacy and safety. Law enforcement agencies and privacy rights groups will have to recognize that this is an area that is particularly vulnerable to abuse and lobby for safeguards to protect individual rights. Unfortunately, the users of magnetic cards can't protect themselves, because they have little technical understanding of the technology and consequently don't even know how vulnerable they are and how easily the information can be stored and analyzed without their knowledge.

10. Resources

10.a. Organizations

These organizations are related to the industry and have information of relevance to this chapter. No endorsement of these companies is intended nor implied and, conversely, their inclusion does not imply their endorsement of the contents of this document.

Association for Payment Clearing Services (APACS) - The U.K. national standards body for transaction cards, including those with magnetic stripes, located in London.

Bartington Instruments - A commercial vendor of a variety of surveillance equipment including a line of magnetometers and gradiometers that are especially applicable to the earth sciences and medical and geophysical site surveys. Vehicle-detector surveillance systems are also available. Based in Oxford, England.

Billingsley Magnetics - A laboratory in a magnetically 'quiet' region which is equipped to assemble and characterize magnetic sensors. The president has a background with NASA, NOAA, and the private sector. Products include ultraminiature and high temperature magnetometers, medical gradiometers, and custom applications. Based in Brookeville, Maryland.

Bioelectromagnetics Society (BEMS) - An independent, nonprofit organization of biological scientists, engineers, and medical practitioners established in 1978 to study the interactions of non-ionizing radiation with biological systems. http://bioelectromagnetics.org/

Electronic Funds Transfer Association (EFTA) - An inter-industry trade association advocating the use and advancement of electronic payment systems, located in Virginia. http://www.efta.org/

Francis Bitter National Magnet Laboratory (FBML) - Established in 1961 at MIT to research state-of-the-art magnetic technologies. The Center for Magnetic Resonance was further established within the FBML in the early 1970s. http://web.mit.edu/fbml/cmr/

Geomagnetism/Ørsted-Satellite Group - A geomagnetic research group at the Niels Bohr Institute Department of Geophysics, in Copenhagen, Denmark. http://www.ggfy.ku.dk/

IEEE Magnetics Society - A society with numerous chapters around the world. It supports and sponsors engineering research and applications in magnetism. http://yara.ecn.purdue.edu/~smag/

International Card Manufacturers Association (ICMA) - A worldwide nonprofit association of manufacturers that serves the dynamic plastic card industry and related industries, located in New Jersey. http://www.icma.com/

International Organization for Standardization (ISO) - A significant international standards organization, located in Geneva, Switzerland. http://www.iso.ch/

Magnetic Materials Program - A National Institute of Standards and Technology (NIST) program to obtain scientific measurements of key magnetic properties and fundamental research of magnetic characteristics, particularly for new materials. Thus, NIST seeks to accelerate the use of advanced magnetic materials by the industrial sector. http://www.msel.nist.gov/magnetic.html

Marine Magnetics Corporation - A commercial vendor and renter of magnetic and gradiometer marine and land exploration devices and equipment. Based in Ontario, Canada.

National High Field Magnetic Field Laboratory (NHMFL) - Funded by the National Science Foundation, the U.S. Dept. of Energy, and the State of Florida, the lab conducts and supports research in high magnetic fields and instrumentation. There are three labs, including the Pulsed Field Facility at Los Alamos National Laboratory. http://www.lanl.gov/orgs/mst/nhmfl/welcome.html

National Institute of Standards and Technology (NIST) - An agency of the U.S. Department of Commerce Technology Administration, established in 1901 as the National Bureau of Standards, located in Maryland. http://www.nist.gov/

Topical Group on Magnetism and its Applications (GMAG) - A special interest group of the American Physical Society. There is discussion of the science of magnetism and also in magnetic recording technologies that are used in the computer industry. http://www.aps.org/units/gmag/index.html

10.b. Print

Arnold, J. Barto, “Marine Magnetometer Survey of Archaeological Materials Found Near Galveston, Texas,” Austin: Texas, 1987, 53 pages.

Asimov, Isaac, “Understanding Physics: Light, Magnetism, and Electricity,” New York: New American Library, 1969, 249 pages.

Bond, Clell L., “Palo Alto Battlefield: A Magnetometer and Metal Detector Survey,” Texas A&M University, Cultural Resources laboratory, Sept. 1979, 63 pages.

Chikazumi, S., “Physics of Magnetism,” New York: Wiley, 1964, 554 pages.

Davy, Humphry, “Further researches on the magnetic phænomena produced by electricity; with some new experiments on the properties of electrified bodies in their relations to conducting powers and temperature,” London, 1821.

Davy, Humphry, “On a new phenomenon of electro-magnetism,” London, 1823.

Jianming, Jin, “Electromagnetic Analysis and Design in Magnetic Resonance Imaging,” Boca Raton, Fl.: CRC Press, 1998, 304 pages. An introduction to MRI with an analysis and survey of the components of a system, the magnet and coils. Includes analytical and numerical methods for analyzing electromagnetic fields in biological objects.

Maxwell, J. C. (Clerk-Maxwell, James), “A treatise on electricity and magnetism,” Oxford: Clarendon Press, 1873.

Morrish, A. H., “The physical principles of magnetism,” New York: Wiley, 1965, 680 pages.

Smart, J. S., “Effective field theories of magnetism,” Philadelphia: W. B. Saunders Co., 1966, 188 pages.

Articles

Coulomb, C., “First and second memoirs on electricity and magnetism,” Institut de France, *Memoires de l’Academie des Sciences for 1785*, 1788.

Rezai, Ali R.; Mogilner, Alon, “Introduction to Magnetoencephalography,” NYU Medical Center Department of Neurosurgery.

Sieber, U., “Computer Crime and Criminal Information Law: New Trends in the International Risk and Information Society.” This describes many types of risks associated with computer data, including data found on magnetic tapes and on smart cards.

Journals

“BioElectroMagnetics Journal,” published by Wiley-Liss, Inc. for the Bioelectromagnetics Society and the European Bioelectromagnetics Association.

“Bulletin of Magnetic Resonance,” a journal of the International Society of Magnetic Resonance.

“Geophysical Journal International,” published for the Deutsche Geophysikalische Gesellschaft, the European Geophysical Society, and the Royal Astronomical Society. It is a leading solid earth geophysics journal covering theoretical, computational, and observational geophysics.

“IEEE Transactions on Magnetics,” sponsored by the IEEE Magnetics Society, with articles on magnetic materials, magnetism, numerical methods, recording media, magnetic devices.

“Magnetic Resonance Imaging,” an Elsevier Science publication. International multidisciplinary journal dedicated to research and applications. http://www.elsevier.nl/

“Magnetic Resonance Quarterly,” a publication of Raven Press.

“Magnetic Resonance Review,” by Gordon Breach Publishers.

“Solid State Nuclear Magnetic Resonance,” Elsevier Science publication.

10.c. Conferences and Workshops

Many of these conferences are annual events that are held at approximately the same time each year, so even if the conference listings are outdated, they can still help you determine the frequency and sometimes the time of year of upcoming events. It is very common for international conferences to be held in a different city each year, so contact the organizers for current locations.

Many of these organizations describe the upcoming conferences on the Web and may also archive conference proceedings for purchase or free download.

The following conferences are organized according to the calendar month in which they are usually held.

“Joint MMM-Intermag Conference,” 8th annual conference, San Antonio, Texas, 8-11 Jan. 2001.

“Card-Tech Secure-Tech,” 10-13 April 1995. This conference took place some time ago, but the Conference Proceedings printed after the event are of interest.

“Symposium on Magnetic Materials for Magnetoelectronic Devices,” Iowa State University, Iowa, 17-18 May 2000.

“Physics of Magnetism 99,” Poznan, Poland, 21-25 June 1999.

“ICM 2000,” international conference on magnetism, Recife, Brazil, 6-11 Aug. 2000.

“Biomag2000,” 12th international conference on biomagnetism, Helsinki, Finland, 13-16 Aug. 2000.

“Hermann von Helmholtz Symposium: New Frontiers and Opportunities in Biomagnetism,” Berlin, Germany, 21 Aug. 2000.

“Applied Superconductivity Conference,” Virginia Beach, Virginia, 17-22 Sept. 2000.

“International Symposium on Magnetic Materials, Processes, and Devices,” 6th annual symposium of the Electrochemical Society, Inc., Phoenix, Arizona, 22-27 Oct. 2000.

“Asia Pacific Magnetic Recording Conference,” Tokyo, Japan, 6-8 Nov. 2000.

10.d. Online Sites

The following are interesting Web sites relevant to this chapter. The author has tried to limit the listings to links that are stable and likely to remain so for a while. However, since Web sites do sometimes change, keywords in the descriptions below can help you relocate them with a search engine. Sites are moved more often than they are deleted.

Another suggestion, if the site has disappeared, is to go to the upper level of the domain name. Sometimes the site manager has simply changed the name of the file of interest. For example, if you cannot locate http://www.goodsite.com/science/uv.html *try going to* http://www.goodsite.com/science/ *or* http://www.goodsite.com/ *to see if there is a new link to the page. It could be that the filename* mgntc.htm *was changed to* magnetic.html*, for example.*

AIM, Inc. This international trade association for manufacturers and providers of automatic identification products has a Web site with a high proportion of educational content, including information on card systems, electronic article surveillance, standards organizations with addresses, glossaries for each subject area, and conversion charts and illustrations. It's a pleasure to come across a site like this. Recommended. http://www.aimglobal.org/

The Basics of Electronic Commuications. This is aimed at children and youth, but can be enjoyed by all. It includes colorful, well-illustrated introductory information on sound, light, electricity, magnetism, and other technology-related phenomena. The characteristics of magnets are discussed as is the relationship between electricity and magnetism.
http://park.org/Japan/NTT/DM/html_st/ST_menu_4_e.html

Electricity and Magnetism. IPPEX Interactive has a Quicktime interactive introduction to electricity and magnetism. IPPEX provides online pages on matter, electricity, magnetism, energy, and fusion. There is also an opportunity to ask a scientist a question through email.
http://ippex.pppl.gov/ippex/module_4/intro.html

Magnet Facts. A short list of some of the things we know and some of the things we don't know about magnets. There are also links to information on types of magnets and magnetic coils.
http://www.technicoil.com/magnetism.html

Magnetic Units and Symbols Conversion Charts. A useful set of tables for converting the units used for expressing various aspects of magnetism and associated symbols. Sponsored by Miller at Iowa State University. http://www.public.iastate.edu/~miller/tables/convert2.htm

TravInfo® System. A traveler information system for the Bay Area that detects and reports traffic flow and speed, especially over well-traveled bridge routes. The system is based in part on the data from magnetic sensors and data about and from individual sensors can be downloaded from the site. The system allows the user to check travel information for a specific route. There is also information on the scope of the project when it is fully implemented. The program is based on an Intelligent Transportation System (ITS) Field Operational Test (FOT) approved by the Federal Highway Administration. http://www.travinfo.org/ http://www.erg.sri.com/travinfo/

10.e. Media Resources

Many science and technology museums have exhibits relating to the history and science of magnetism, too many to list, so here are just a few examples.

Museum of Science and Industry. Located in Chicago, Illinois, this extensive exhibition space includes an "Idea Factory" a learn-through-play section that allows youngsters to observe and test the basic concepts of mechanics, light, color, and magnetism.

Science Center of the Americas. The Miami Museum of Science and the Smithsonian Institution are developing America's first international science center. The Hands-on Hall of Science will feature a number of science and technology exhibits, including biomedicine, telecommunications, and others.

Whipple Museum of the History of Science. Located at the University of Cambridge, in the U.K., the exhibits include magnetic materials, lodestones, bar magnets, and a very rare amplitude compass.

11. Glossary

Titles, product names, organizations, and specific military designations are capitalized; common generic and colloquial terms and phrases are not.

ABA track	ANSI/ISO standardized data track #2 encoded in BCD format
AIDC	automatic identification and data capture, e.g., as is accomplished with cards with magnetic strips
air gap	a nonactive section or break in a magnetic surface circuit
ATB	automatic ticketing and boarding, a magnetically coded ticket system used by airlines and other forms of public transportation to expedite passenger boarding
ATM	automatic teller/transaction machine
bulk eraser	a strong magnetic 'scrambling' unit used to 'remove' the ordered magnetic patterns (but not the magnetic character) of a magnetic data medium such as a floppy disc or coded card
CENELEC	Comité Européean de Normalisation Electrotechnique, a European telecommunications regulating authority
degaussing	the process of demagnetizing a substance or system. Some systems build up a magnetic charge over time (e.g., computer monitors) that can eventually interfere with the functioning of the system and must be periodically degaussed to remove the source of the interference.
doping	the process of embedding tiny amounts of magnetic or other materials to increase the conductivity or magnetizability of a substance
EAS	electronic article surveillance, electronic access surveillance, electronic access system
EM	electronically magnetized/magnetizable
f	a symbol for magnetic flux
FCC	Federal Communications Commission, the primary U.S. body for radio frequency transmissions and emissions regulation
Gilbert	a centimeter-gram-second (CGS) unit of magnetomotive force
Henry	a unit and associated symbol (H) for magnetic field strength or magnetic inductance
MCCL	magnetic-code computer lock
NMR	nuclear magnetic resonance
Oersted	or Ørsted, a unit and associated symbol (Oe) for magnetic intensity
ordnance	(not to be confused with ordinance, which is a decree) military supplies and equipment such as weapons, land mines, vehicles, etc.
remote sensing	sensing at a distance, which is usually, though not always, non-destructive (remote-sensing of biological specimens with X-ray technology may have destructive effects)
sampling, probabilistic	a mathematical technique used in forensics and archaeology to interrelate small samples to larger populations or amounts, in other words, mathematically extrapolating information from what is at hand from information that is already statistically known or calculated

tesla	a standard international (SI) unit and associated symbol (T) for magnetic flux density
UOD	unexploded ordnance detection, the detection of undetonated explosives such as land mines or bombs
UXO	unexploded ordnance, see UOD
Weber	a standard international (SI) unit and associated symbol (Wb) for magnetic flux