United States Patent [19]

Fearon

[11] **3,790,945**

[45] **Feb. 5, 1974**

[54] **OPEN-STRIP FERROMAGNETIC MARKER AND METHOD AND SYSTEM FOR USING SAME**

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[73] Assignee: **Stoplifter International, Inc.**

[22] Filed: **Nov. 24, 1971**

[21] Appl. No.: **201,686**

Related U.S. Application Data

[60] Division of Ser. No. 747,050, March 22, 1968, Pat. No. 3,631,442, and a continuation-in-part of Ser. No. 680,666, Nov. 6, 1967, abandoned.

[52] **U.S. Cl.** .... **340/280,** 325/8, 340/258 R, 343/6.5 SS, 343/787

[51] **Int. Cl.** **G08b 13/24**

[58] **Field of Search**.... 340/258 R, 258 C, 280, 224; 325/8, 105; 343/6.5 SS, 6.8, 787, 788; 179/82

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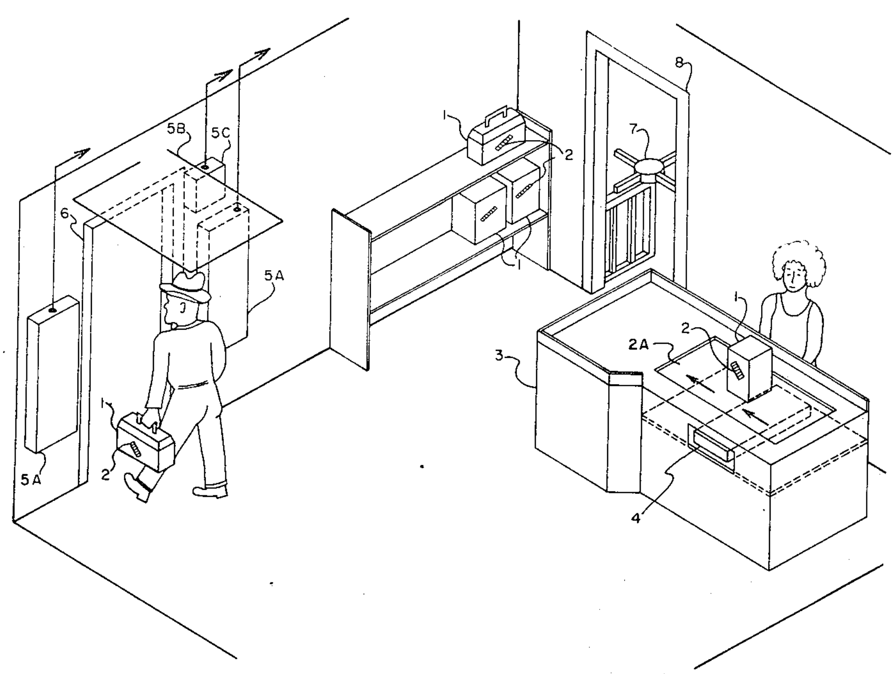
Primary Examiner—David L. Trafton

[57] **ABSTRACT**

The specification describes an open-strip marker for use in detecting the presence of an object in an interrogation zone. Each object to be detected is provided with a marker comprising an elongated ferromagnetic element having a high permeability and a high ratio of length to cross-sectional area. A periodically varying magnetic field is provided in an area through which the object is to pass. Upon passage of the object through the area, reversal of the magnetization of the marker results in a uniquely characteristic signal for each alternation of the electromagnetic field. This characteristic signal is sensed to distinguish the presence of the object.

18 Claims, 9 Drawing Figures



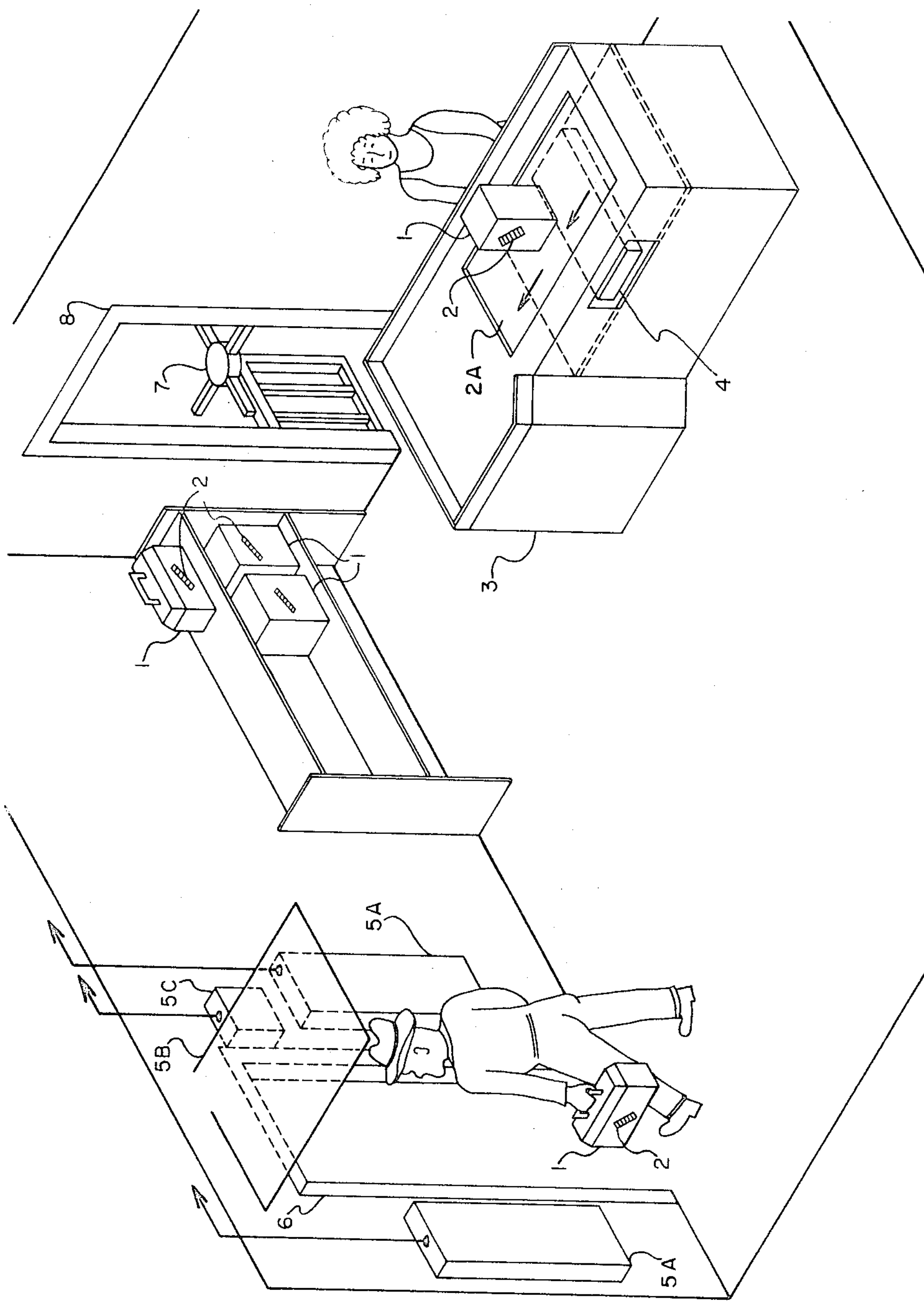


FIG. 1

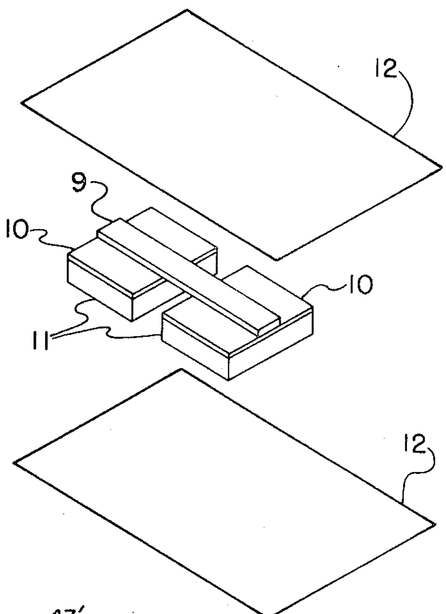


FIG. 2

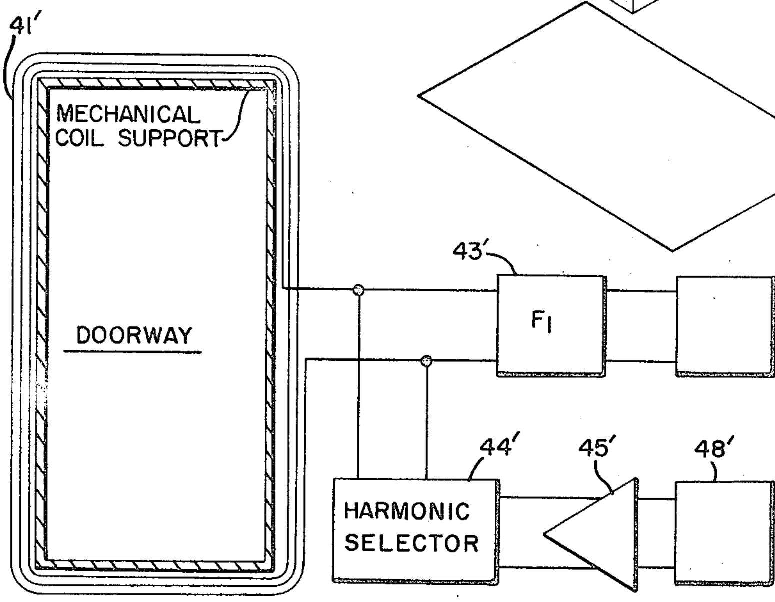


FIG.9

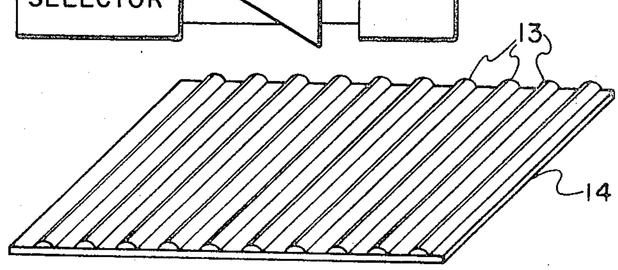


FIG. 3

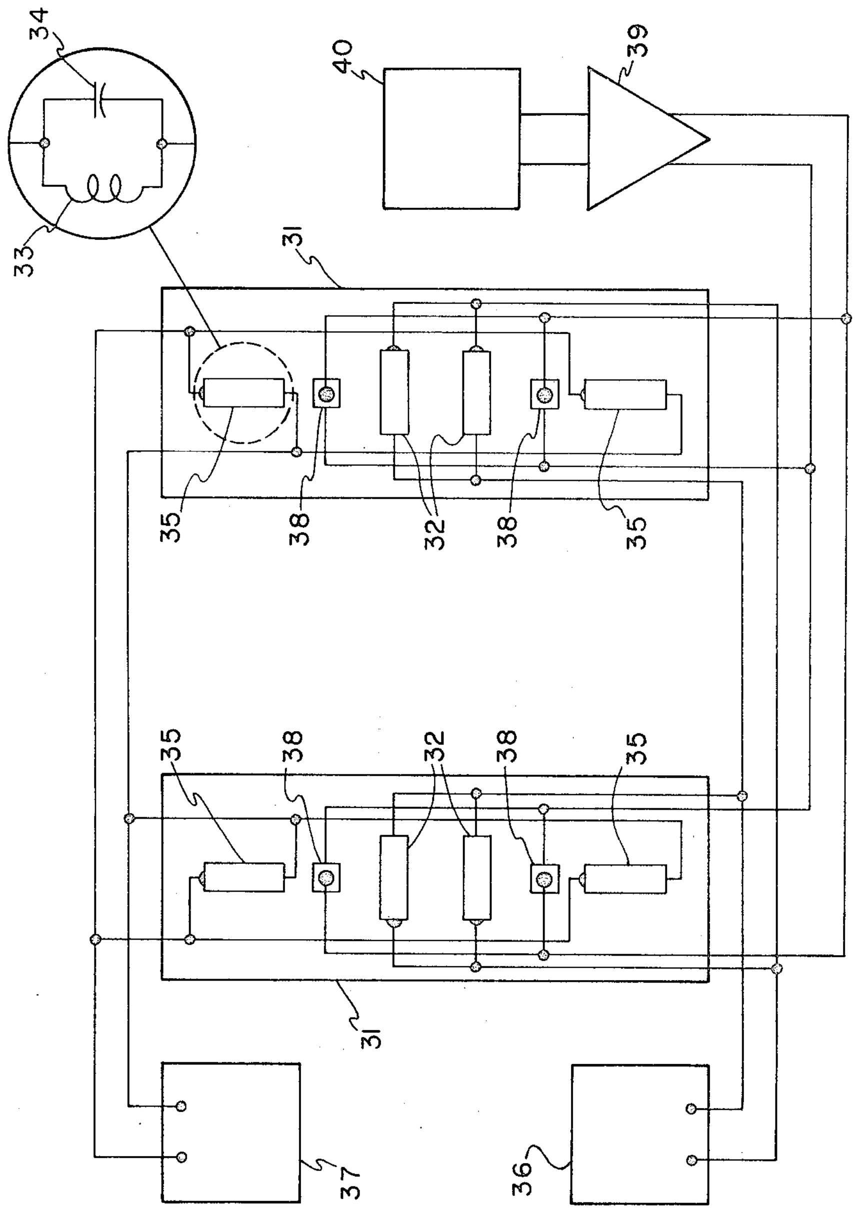


FIG. 4

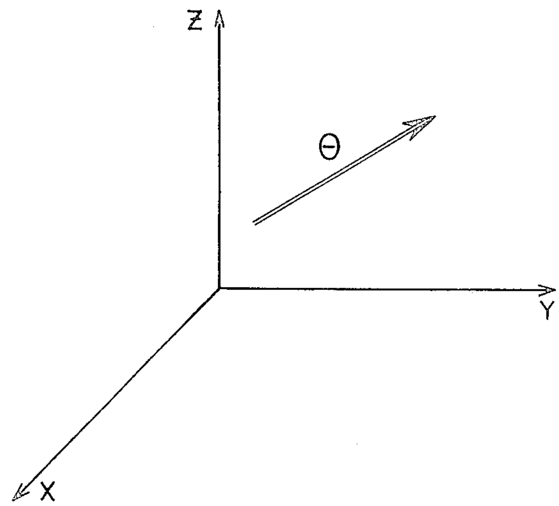

Z
Θ
Y
X

FIG. 5

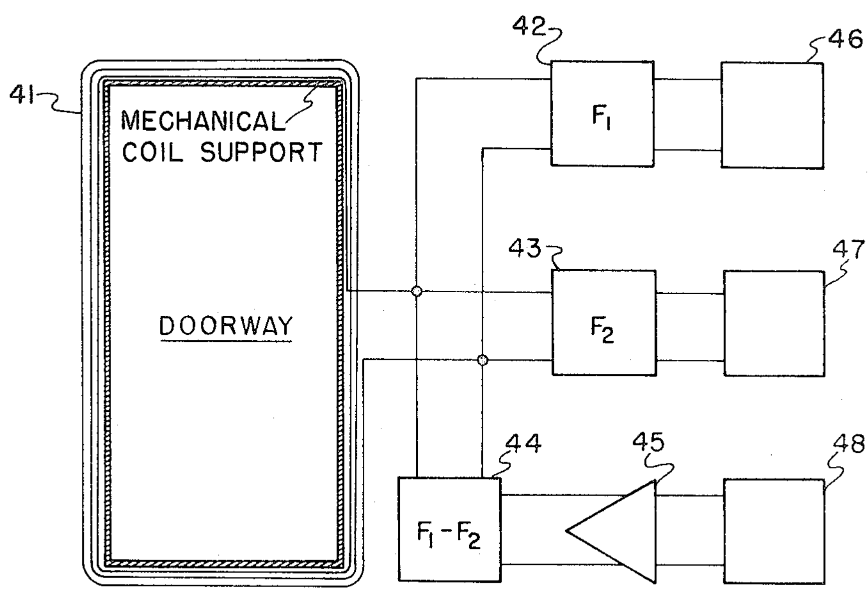

41
MECHANICAL
COIL SUPPORT
DOORWAY
42
F1
46
43
F2
47
44
F1 - F2
45
48

FIG. 6

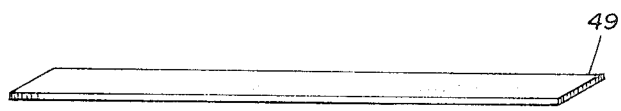


FIG. 7

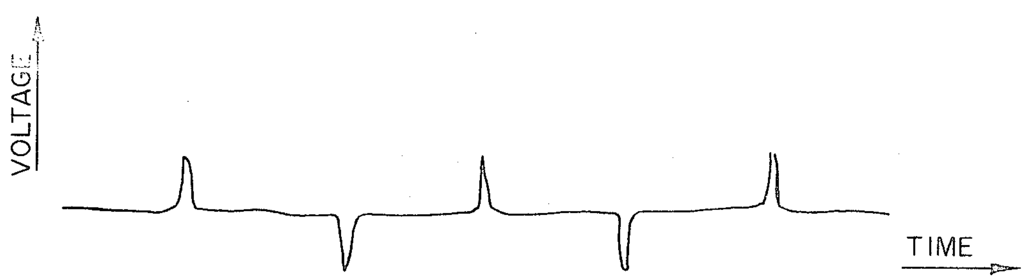


FIG. 8

OPEN-STRIP FERROMAGNETIC MARKER AND METHOD AND SYSTEM FOR USING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. Patent application Ser. No. 747,050, filed Mar. 22, 1968, now U.S. Pat. No. 3,631,442, which was filed as a continuation in part of now abandoned patent application Ser. No. 680,666 filed Nov. 6, 1967.

FIELD OF THE INVENTION

This invention relates to object detection, and more particularly relates to object detection in such applications as anti-pilfering and sortation systems.

THE PRIOR ART

There are in existence several systems for detecting or preventing the theft of articles of value. One of these corresponding with U.S. Pat. No. 3,292,080, granted to E. M. Trikilis, Dec. 13, 1966, makes use of a magnetometer and utilizes a magnetized object which identifies the article unless checkout procedure has removed the magnetism from the object. The magnetized object is attached to or becomes a part of the merchandise or article of value, and by energizing the magnetometer system as it passes through the doorway, is detected. If the magnetized object has been demangetized it causes no magnetic signal as it passes through the doorway and is not detected. Demagnetizing is done in the process of checking out the merchandise. Thus by the checkout procedure an individual has free passage with the merchandise that has been paid for or recorded by the clerk. Any additional merchandise not paid for and however concealed radiates a magnetic influence, and energizes the magnetometer at the doorway, creating an awareness of security department personnel that something is being stolen.

Another system involves radioactive material which emits nuclear radiation. When the label containing the magnetic material is removed from the merchandise, the radiation is no longer emitted, and therefore radiation detectors situated in the doorway are not energized. On the other hand, if the radiation emitters remain on the merchandise, doorway sensors of nuclear radiation react, and security personnel are in a position to prevent the theft.

In another system currently being employed in a men's wear department in Macy's in New York City, the operator uses a radio frequency generating device embedded in a rubber pad. The radio frequency emitting device is fastened to the men's clothing, and if not removed, will energize radio frequency detecting antennae at the doorway. In the normal course of events, when the merchandise is sold, a special fastener is unlocked and the radio frequency emitter is removed from the clothing at the time it is sold, permitting the buyer to pass through the doorway without attracting the attention of the store detective.

Another system specifically intended for use in antipilferage application is described in a 1934 French Pat. No. 763,681, issued to Pierre Arthur Picard, which discloses a remote detection system employing dynamic magnetic phenomena to detect the presence of an object, e.g., a book being carried through a doorway. The system of Picard is based upon the discovery that a piece of metal subjected to a sinusoidally varying magnetic field induces in a pair of balanced pickup coils in the vicinity of the applied field a voltage characteristic of the metal. The patent indicates that high permeability metals produce an induced voltage including higher order harmonics of the sinusoidal field than the harmonics of metals such as iron. Permalloy is listed as a high permeability material from which the characteristic voltage contains ninth and eleventh harmonic components, unlike such common metals as copper, iron, or aluminum, which produce practically no harmonics of such a high order.

According to the Picard patent, only the composition of a metal determines the order of the harmonics present in its characteristic voltage. It is disclosed that marker size and geometry affect the amplitudes of all frequency components proportionately. Accordingly, the ratio of two individual harmonic components for a particular material would be the same regardless of the material's size or geometry. The Picard patent further discloses that the ratio between at least certain selected components is characteristically different for different materials. Picard emphasizes that the size of the metal piece to be used as a marker is important; not to control the order of the harmonics present, but rather to provide a signal large enough to be detected.

All of the foregoing systems have severe difficulties of one kind or another. The Trikilis system requires a rather large piece of ferromagnetic material for the marking of the merchandise. If too small a piece of ferromagnetic material is used, ambient variations in the magnetic field are greater than the changes caused by the Trikilis merchandise marker. In the case of the radioactive dot, there is a severe health problem involving danger to people from the nuclear radiation, and involving danger to those who remove the markers and store them. The system in use in Macy's Store unfortunately is limited by the extreme costliness of the radio frequency transmitter, and the limited period of time during which its emission can be maintained by the little batteries with which it is provided. True, larger radio frequency emitting pads could be made, but these tear or injure the clothing and are impractically bulky.

The Picard patent fails to appreciate the dependence of the harmonic signal on the shape of the high permeability element. The resultant detection of signals containing only nine to 11 order harmonics, e.g., frequencies on the order of 650 Hz when excited by a 50 Hz field, allows the occurrence of false alarms resulting from the presence of other magnetic materials as well as relatively common electrical noise. The Picard system purports to avoid such limitations by measuring the ratio of two harmonics.

SUMMARY OF THE INVENTION

I have discovered a practical solution to the problems presented but not solved by the workers in the prior art as described above. As a matter of convenience, I choose to employ electromagnetic radiation. However, because of the inconvenience of supplying energy in a contraband marking, the energy to be radiated from the contraband marked device is delivered, instead, from structural members of my sensing doorway.

I have found it extremely difficult to re-radiate or reflect energy in a distinctive manner from any merchandise marker for the reason that all solid bodies and all electrically conductive masses (including the human body which is largely composed of salt water) also reflect or disperse electromagnetic radiation and therefore must be considered in the recognition of any merchanidse marking. A human being reflects more electromagnetic energy than any practical size of merchandise marker.

I have solved the problems just described by my discovery of an extremely simple device which can receive energy and re-emit it, receiving the energy in a frequency spectrum entirely distinct from the frequency spectrum which is re-emitted. I do this by making use of the properties of electrically and electromagnetically nonlinear systems. In general, it is the property of a nonlinear system that if a frequency F is imposed at an energy level at which the nonlinearity of the system becomes important, the system will generate frequencies 2F, 3F, 4F, etc. Similarly, when signal sources are imposed on a nonlinear system, the sources delivering approximately equal energy in each of two frequencies, the nonlinear system will generate other frequencies, not originally present. If the frequencies imposed are F_1 and F_2, the nonlinear system will generate signals having frequencies $F_1 + F_2$, $F_1 - F_2$, $F_1 + 2F_2$, $2F_1 + 2F_2$, and various other combinations of sums and differences of multiples of the frequencies imposed. It is an essential part of my invention that I have discovered a merchandise marker which constitutes a nonlinear system and which therefore can generate phenomena such as those which have just been discussed.

I have discovered a theft detection and prevention system which comprises a surveillance doorway containing among other things emitters of electromagnetic energy adapted to emit electromagnetic energy into a region of space. My system also includes an electromagnetic signal detection means situated at or near the surveillance doorway designed and adapted to receive energy re-radiated from a merchandise marker device.

In accordance with a more specific aspect of the invention, a marker is provided which, when secured to an object, enables the detection of that object in an interrogation zone such as a doorway. Such a zone has a magnetic field periodically varying at a predetermined fundamental frequency. The marker comprises an elongated ferromagnetic element of high permeability which is capable of responding to the magnetic field to generate cusp-like signals containing harmonics of the fundamental frequency of very high order. Such a marker preferably has dimensions to provide a very high ratio of length to cross-sectional area, and further has a permeability in the range of 400,000 or greater, and a coercivity of about 0.02 oersteds. In this invention, not only is a larger detectable signal produced by the marker than is produced by pieces of the same material not having the necessary dimensions, but by specially selecting the dimensions of the marker, the signal resulting from the presence of the very high harmonics is far greater than that resulting from greater amounts of the same materials having non-preferred dimensions. Such harmonics are many times higher order than those observed by Picard or obtainable in any materials except the specially selected shapes of uncommon metals, thereby providing a system not susceptible to false alarms. Furthermore, the marker of my invention readily lends itself to concealment in various articles of merchandise, making compromise of my system difficult.

The present invention is further directed toward a system for detecting the presence of an object when the object is in an interrogation zone such as a doorway, in which the zone has a magnetic field periodically varying at a predetermined fundamental frequency. The system comprises the marker as described above, a radiating means for producing the magnetic field within the interrogation zone having an intensity sufficient to reverse the magnetization of the marker element when in the zone, a receiving means for detecting cusp-like signals containing the high order harmonics of the fundamental frequency which are produced by the ferromagnetic element, and a security readout and communications means coupled to the receiving means responsive to the signal to indicate the presence of an object in accordance with the harmonic content. In the preferred embodiment, the marker element is positioned in the zone with its axis approximately parallel with the magnetic field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a somewhat diagrammatic view of a typical installation of the system of the invention;

FIG. **2** illustrates one form of a contraband marking element for use in the present system;

FIG. **3** illustrates another embodiment of a marker for use with the invention;

FIG. **4** is a schematic of an embodiment of a system for radiating electromagnetic energy to detect the presence of a marker according to the invention;

FIG. **5** is a diagram to assist in explaining the operation of the present energizing and detecting system;

FIG. **6** is a diagram illustrating the filter and coil system of the invention;

FIG. **7** illustrates the preferred claimed marker of the present invention;

FIG. **8** illustrates a typical waveform generated by the preferred marker shown in FIG. **7**; and

FIG. **9** illustrates the harmonic detection system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

I now turn to FIG. **1** which is a general view of the manner in which the present system operates in a store to prevent theft of merchandise. Merchandise **1** is provided with contraband marker elements **2.** The checkout stand area **3** contains a deactivating device **4** which is capable of changing the electromagnetic properties of the contraband marker elements **2.** An energizing and detecting system **5A** situated in the **5B** and **5C** vicinity of the outgoing doorway **6** detects the contraband marker elements **2,** and identifies those which have not been subjected to change at the checkout stand area **3** by the deactivating device **4.** In the use of my system, one way traffic, enforced by perhaps a turnstile **7,** takes care of persons entering the store, prohibiting the carrying of merchandise from the store to areas outside the store except through my outgoing doorway **6.** The turnstile **7** is provided at the entry portal **8.**

I turn now to FIG. **2** which illustrates one form of contraband marking element suitable for use in my system. The element includes an easily saturable high permeability filament or narrow ribbon **9** of specialized magnetic material such as the one known by the tradename Superpermalloy, which has a maximum permeability of over 800,000 and a coercive force of about 0.002 oersteds. The filament extends parallel to, and is so situated as to collect the magnetic flux from two pole piece coupons **10** which are also composed of high quality magnetic material of the type having a very low coercive force and a very high maximum magnetic permeability. In this embodiment, the coupons **10** are preferably composed of materials having a maximum permeability in the vicinity of 50,000 or thereabouts. Attached to the coupons **10** I provide masses of rigid plastic substance such as polymerized methyl methacrylate **11**. In use, the device is assembled between layers of paper **12** (or plastic) illustrated in exploded view (removed from the vicinity of the filament **9** and coupons **10**). The filament **9** and coupons **10** are not shown in exploded form, but are illustrated realistically. In use, the filament **9** is spaced from the coupons **10** by a few thousandths of an inch, the space being occupied by a lubricating particle suspension such as silicone oil with magnesium oxide particles in it. Any other suitable lubricant may be employed, together with particles of suitable size. For example, petroleum lubricant and carbon particles are satisfactory. Fluorocarbon oil with bentonite clay suspended in it is suitable. In use of the FIG. **2** device, the space between the filament **9** and the adjacent layer of paper **12** is also filled with a suitable particle suspension lubricant, to space the filament **9** apart from the paper **12** by an appropriate distance.

In use, the contraband assembly described in FIG. **2** encounters, at the outgoing doorway **6** of FIG. **1**, a combination of electromagnetic fields producing an oscillating component of magnetic field parallel with the axis of the filament **9**. In one embodiment, the oscillating component of magnetic field, as provided in the outgoing doorway **6**, includes contributions of two separate frequencies. The magnetic fields thus provided have a component parallel to the axis of the filament **9** as shown in the FIG. **2** device, and are of sufficient magnitude to bring about a substantial degree of magnetic saturation of the filament **9** parallel to its axis. Because of the nonlinearity of the magnetic phenomena occurring in the filament **9**, summation and difference tones are produced and radiated in the form of electromagnetic radiation from the device shown in FIG. **2**. The above described phenomena occur when merchandise **1** (FIG. **1**) carrying a contraband marker element **2** shown in detail in FIG. **2** is taken through the outgoing doorway **6** (FIG. **1**) without paying for it.

When, on the other hand, the customer pays for the merchandise **1** (FIG. **1**) the merchandise **1** (FIG. **1**) is presented in the vicinity of the deactivating device **4** (FIG. **1**) in the checkout stand area **3** (FIG. **1**). The deactivating device **4** (FIG. **1**) delivers an extremely strong magnetic field, a field so strong that it is sufficient to induce a very large magnetic flux not only through the filament **9**, but also in the coupons **10** of the device of FIG. **2**. The large magnetic flux induced in the coupons **10** (FIG. **2**) by the deactivating device **4** (FIG. **1**) would normally bring about an elongation (or in some instances possibly a shortening) of the material composing the coupons **10** (FIG. **2**) in the direction in which the magnetic flux is induced.

However, the plastic substance **11** attached to each coupon **10** is rigid and non-magnetic. The plastic substance **11** being firmly attached to the coupons **10** resists the dimensional change which would otherwise occur due to a strong magnetic flux in the coupons. The clamping effect which the plastic substance **11** thus exerts corresponds with a mechanical strain improsed on the magnetic material of the coupons **10**. The mechanical strain being beyond the elastic limit of the said magnetic material, it undergoes cold-work which destroys its superior magnetic properties, degrading its maximum permeability from the vicinity of 50,000 to the general vicinity of one or two thousand.

A FIG. **2** device assembled as described in the foregoing paragraph and deactivated as described, still has demonstrable nonlinear magnetic properties. However, the doorway field intensity required to induce nonlinear behavior of the filament **9** is substantially altered, for the reason that the maximum permeability of the coupons **10** being lowered, they do not collect magnetic flux from the outgoing doorway **6** environement and feed it into the filament **9** as efficiently as they did before their magnetic properties were degraded. Thus it is possible for an energizing and detecting system **5** existing in the vicinity of the outgoing doorway **6** to determine the presence of unsold merchandise **1**, and at the same time be sensitive to the fact that the same individual, or one nearby, is also carrying merchandise which has been properly paid for and carries deactivated contraband marker elements **2** (FIG. **1**). (I note that the contraband marker elements **2**, as actually illustrated in FIG. **1**, are not deactivated, being shown inside the store area.)

FIG. **3** illustrates a modified form for the coupons **10** (FIG. **2**). In this modified form the coupons **10** are not attached to any plastic clamping substance **11** over their entire surface, but material of a different nature, either more or less magnetic than the material of the coupons, or not magnetic at all, is deposited in a periodically spaced pattern in a plurality of closely spaced stripes **13** equi-distant from each other on the specially arranged coupon **14**, which has properties generally similar to the properties of the coupons **10** of FIG. **2**. Because of the mass of such periodically spaced stripes **13**, and because of their other properties by which they are differentiated from the magnetic material composing the specially arranged coupon **14**, the specially arranged coupon **14** in combination with the stripes **13**, exhibits a mechanical resonance tending to vibrate in such a manner that the material situated at the stripes **13** undergoes a minimum of movement and/or dilatation. If mass is the predominant characteristic of the material at the stripes **13**, the stripes **13** will correspond with a minimum of movement. If mechanical stiffness predominates, the stripes **13** will correspond with very little change of dimension at the frequency of the resonance, and with the specially arranged coupon **14** vibrating in the resonant mode. Because of the influence of the periodically spaced stripes **13**, the specially arranged coupon **14** will always exhibit a sharply determined mechanical resonance in the manner just described.

When using contraband marker elements **2** manufactured generally in accord with FIG. **1**, but provided with specially arranged coupons **14**, the deactivating device **4** (FIG. **1**) should be energized at the frequency corresponding with the resonance, or the deactivating device **4** should be made resonance seeking with respect to the desired mode of mechanical motion. Inducing the resonant motion, the deactivating device **4** (FIG. **1**) causes mechanical energy to build up in the specially arranged coupon **14** until the amplitude of movement and the amplitude of stress and strain involved in the resonant oscillations approaches the elastic limit of the magnetic material composing the specially arranged coupon **14.** As has been described before in conjunction with the deactivation of coupons such as the coupons **10** (FIG. **2**), the coldwork result from the movement causes the magnetic properties of the specially arranged coupons **14** to be degraded from the general vicinity of a maximum permeability of 50,000 to a maximum permeability in the vicinity of one to two thousand. As before, the contraband marker elements **2** (FIG. **1**) in which coupons of whatever type have been degraded, are recognizable, and may be differentiated from other contraband marker elements **2** (FIG. **1**) which have not passed through the deactivating process, and not had their coupons degraded.

Although the provision of periodically deposited stripes **13** on the specially arranged coupon **14** helps to define and select a particular resonance at which the specially arranged coupon **14** will oscillate, as will be later described in detail, the coupon without stripes **13** and without the plastic substance **11** (FIG. **2**) can also be induced to oscillate in a resonance mode. In fact resonant oscillations can be induced at a wide variety of modes comprising an extensive plurality of possible choices of resonant frequencies. This, in fact, is the chief difference between an ordinary unclamped coupon such as the coupon **10** of FIG. **2** (but without plastic substance **11** and without stripes **13** as provided in FIG. **3**) and the specially arranged striped coupon **14** of FIG. **3.** Because of the stripes, the specially arranged coupon **14** of FIG. **3** prefers a particular mode of resonant oscillation and the striped structure **13** tends to suppress the other modes which are a feature of an unclamped and unstriped coupon. In fact the convenience of the stripes lies in this, that the otherwise extremely large diversity of possible oscillatory frequencies is reduced by the stripes **13** to one chosen and preferred mode and frequency. Through the provision of this feature, a specially arranged coupon **14,** because of its thickness, mechanical characteristics, and because of the periodicity of the stripes **13,** is distinctly recognizable and can be differentiated at the outgoing doorway **6** (FIG. **1**).

Thus it is possible, using the present system, and using the provisions of my FIG. **3** to distinctly characterize the contraband marker elements **2** (FIG. **1**) being employed by Woolworth's, or for example by Sears Roebuck. In fact, using the recognition capabilities intrinsic in contraband markers thus manufactured, the outgoing doorway **6** energizing and detecting system **5** (FIG. **1**) can report at the Sears Roebuck store when it detects merchandise **1** that was stolen at Woolworth's and determine that it is Woolworth merchandise that is being observed.

Attention is now directed to the energizing and detecting system **5** (FIG. **1**) situated in the outgoing doorway **6** (FIG. **1**). Because there are three perpendicular coordinates available in space of three dimensions, two energizing systems and detecting devices can be arranged to work in a non-interacting manner. In fact, it is a characteristic of one embodiment of the invention that within the limits of accuracy of adjustment of the position and orientation of the electromagnetic radiating and receiving components, two radiating components radiate independently, neither one being capable of transmitting energy into the other one, and further, the detecting or receiving pickup does not receive energy directly from either of the radiating devices. These arrangements of course are valid only when the space in the doorway is empty, there being no contraband marker elements **2** (FIG. **1**) in it. This type of arrangment which has been generally recited above is depicted in more detail in FIG. **4.**

In FIG. **4** I have pictured two pedestals **31,** each containing near its center a pair of sending coils **32.** All the sending coils **32** are connected in parallel (or they could have been connected in series). For illustration only, I will suppose that the frequency by which these sending coils **32** are energized is 21 kilohertz. Each such sending coil **32** is separately tuned to exhibit the highest possible impedence at 21 kilohertz. For illustration only, the coil may be composed of 99 turns of No. 20 copper wire wound on a 1 inch diameter coil form in a single layer to produce 99 turns in a total length of 3-½ inches. Such a coil may be resonated to 21 kilohertz by the use of an electrical capacity of not less than 1 microfarad and not more than 1.1 microfarad. The combination of one of these coils **33** with its resonating capacitor **34** (as shown in the inset), when energized at the resonant frequency, represents an entirely resistive impedence and in the illustrative case exhibits a resistance between 100 and 150 ohms. A parallel combination of four such resistive loads has a combined effect adapted to efficiently load the voice coil outputs of some available audio amplifiers.

Similarly, there are situated at the bottom and at the top of each of the pedestals **31,** coils **35** intended for transmitting another chosen frequency such as (for illustration only) 24.5 kilohertz. The four coils **35** which are intended for 24.5 kilohertz radiation may be constructed similarly and resonated similarly, but, of course, resonate with a correspondingly smaller electrical capacity for each coil. The combination of the first group of four coils **32** is connected to a source of electrical energy **36** at 21 kilohertz. The combination of the second group of four coils **35** is connected to a separate, entirely independent, source of electrical energy **37** at 24.5 kilohertz. Because of the arrangement which I have chosen for the first group of coils **32** and for the second group of coils **35,** there is no appreciable mutual inductance acting to deliver 21 kilohertz energy into the 24.5 kilohertz, or vice versa.

At four other locations I present four more coils **38** with their axes perpendicular to the plane of the paper. Because all the contributions of the first group of four coils **32** and the second group of four coils **35** lie in the plane of the paper, the four coils **38** with their axes perpendicular to the plane of the paper do not receive energy neither at 24.5 kilohertz, nor at 21 kilohertz. The four coils **38** with their axes perpendicular to the paper are resonated at 3.5 kilohertz by choosing an appropriate electrical capacitance. In order to achieve good sensitivity in these coils, and in order that they may be resonated efficiently at the frequency of 3.5 kilohertz, more copper is required in the winding, preferably four layers of No. 20 wire, each layer containing 99 turns more or less. The capacity required to resonate such a coil is in the general vicinity of two microfarads for 3.5 kilohertz.

I call attention to the fact that the cores of these windings have not been specified thus far. It is a preferred choice to wind them on non-magnetic, electrically non-conducting material, for the reason that ferromagnetic material (because of its nonlinear properties) imparts to my system undesirable interactions between the energy sources. Electrically conducting material, on the other hand, destroys the quality of the inductive performance of all the coils. As a matter of fact, an air core coil of 99 turns, made in the manner that I have described, has a Q in the vicinity of 500 at 21 kilohertz when wound on a wooden core. The resonance cannot be found, nor the inductance measured well enough to determine the Q if it is wound on an electrical conductor as a core.

The combination of the four coils, as described, with their axes perpendicular to the paper (each coil resonated at 3.5 kilohertz by appropriate electrical capacitance) delivers its output to the ingoing end of a high gain tuned amplifier **39** adapted to selectively receive and amplify electrical signals at 3.5 kilohertz. The amplifier **39** delivers its output to an alarm mechanism **40**, or to a carrier frequency module, which is discussed further on. To achieve a closer impedence match with respect to the commonly prevailing input resistance of the amplifiers that are the most convenient, I may choose to vary from the connections shown in FIG. **8**, and connect the four receiving coils **38** (the ones with their axes perpendicular to the paper) in series. The resistive component of these coils (with their resonators connected) comes out for each such resonated system in the vicinity of 100 ohms, with the result that the seris of four of them are a close match to the communications impedance figure of 500 ohms, a common choice for amplifiers, filters, etc.

I turn now to FIG. **5** presented for the purpose of diagrammatically assisting in the explanation of the manner of functioning of the energizing and detecting system **5** (FIG. **1**) which I have particularly detailed and described in connection with FIG. **4**. In FIG. **5** the axis X may be taken to represent the action of the 21 kilohertz radiator, the perpendicular axis Y illustrates the action of the 24.5 kilohertz radiator, and the axis Z represents the receiving sensitivity or direction of the 3.5 kilohertz receiving coils **38** of FIG. **4**. The vector θ is illustrated in a direction not parallel to nor perpendicular to any of the three axes. The vector θ represents the direction in which a contraband marker element **2** (FIG. **1**) is capable of receiving and re-radiating energy. Because the vector θ has an appreciable component in all three axes, the contraband marker element **2** (FIG. **1**) oriented in accord with this vector is able to receive energy concurrently at 21 kilohertz, and likewise at 24.5 kilohertz. For similar reasons, if the contraband marker element **2** (FIG. **1**) re-radiates at 3.5 kilohertz (not being deactivated) then detection axis Z is so directed with respect to the vector θ that the said detection system is not insensitive to radiation emitted by the contraband marker element **2** (FIG. **1**).

The user, considering the information presented in connection with FIG. **4**, and the information just presented in connection with FIG. **5**, will realize that the reception of a 3.5 kilohertz in the system is a distinctive and an exclusive evidence of the presence of contraband marker elements **2** (FIG. **1**). One or more such elements must be in the domain of energy radiation and sensitivity provided by the arrangements shown in FIG. **4** to deliver a 3.5 kilohertz signal. Other entities than contraband marker elements are not entirely without effect, but they do not present the same effects.

To aid the understanding of another modification of my sistem which I have described, I turn again to FIG. **5**. In FIG. **5** I have represented the directions of action of the energy source frequencies X and Y (21 and 24.5 kilohertz sources) and the direction of sensitiviy of the system that detects the difference tone Z in the form of three perpendicular axes. To the worker skilled in the art, it is evident that if contraband vector θ is exactly perpendicular to either of the signal source axes X or Y, energy is eliminated which corresponds with the vector to which the vector θ is perpendicular. Furthermore, if the vector θ lies in the X – Y plane, it is perpendicular at all times to the axes Z, which therefore prohibits the reception of any energy in the signal receiving system **38**, (FIG. **4**). It is, in fact, true that the vector θ must have appreciable and comparable components or direction cosines aligned with all three of the vectors X, Y, and Z. For those directions θ which do not fulfill these conditions, either the difference tone signals are not produced or they are not observed (if produced) by the contraband marker element **2** (FIG. **1**). The fact that there are so many blind spots and so many requirements on the direction of contraband, causes the system, conceived as in the foregoing, to sometimes fail to recognize contraband markers passing through the outgoing doorway **6** (FIG. **1**). It still remains a fact that nothing other than a contraband marker will ring the alarm. However, a way has been discovered to reduce the inconvenience resulting from the above noted limitations (which now and then permit a contraband marked piece of stolen merchandise to get through).

The user will note in FIG. **4** that in the foregoing I have excluded the energy from the 21 kilohertz source from getting into the 24.5 kilohertz source by arranging for separate radiators, and arranging that these be non-interacting because of their perpendicularity arrangement. Another approach to excluding wrong pathways of signal energy is quite applicable in the frequency range which I have chosen, an approach not dependent on geometry. My modification permits advantages in the simplification of the doorway structure.

The system which is contemplated for the reduction of the number of blind spots in respect to the direction of the vector θ (FIG. **5**) substitutes rigorously designed wave filters, containing passive elements only. These perform the function performed by the geometric isolation in the system of FIG. **4**. Such wave filters can be designed for the range of frequency in the vicinity of 20 to 50 kilohertz without the use of ferromagnetic material or anything else which would impose a nonlinearity. The wave filters thus used, if provided in a sufficient number of sections, propagate the desired energy substantially without loss and are able to reject the unwanted signal frequencies to whatever extent is desired, through the use of a sufficient number of networks. A properly designed M or π derived filter network will exclude unwanted frequencies by over one hundred decibels in just a few networks.

Lattice type filters may be employed for single frequency rejection and are extremely effective. In fact, the only serious limitation on the rejection brought about by a lattice type filter is imposed by variation in frequency of the signal which it is desired to reject. A lattice type filter, for example, may comprise two electrical capacitances and two inductive elements as the four components of a bridge. The input to the bridge and the output to the bridge have a ratio which theoretically is infinite at the frequency at which it balances. Thus it is theoretically possible to exclude a single frequency to any extent, by a single network of such a filter. At the same time a single network lattice filter can transmit very efficiently energy corresponding with signal frequencies that are substantially different from the signal frequency at which the bridge balances.

For 20 kilohertz or more, substantially perfect inductances (inductances with a Q in the realm of thousands) can be delivered in the space of a few cubic inches, and need not contain more than an ounce or two of copper wire. Again in the frequency spectrum involving a metal box comprised of iron or copper, and with a coil spaced from the walls, inside the box, the coil neither radiates nor absorbs electromagnetic energy appreciably in this kilohertz range. Capacitances constructed of aluminum foil and wound with such a dielectric as wax paper (or mylar or polystyrene) give a substantially perfect electrical performance in my preferred frequency range. It is, accordingly, entirely feasible to contemplate the substitution of rigorous filtering in place of the previously described geometric means of arranging radiator coils so that energy is not transferred from one system to another. Moreover, the use of well designed filters has a further advantage, that the presence of conducting bodies of any description in the doorway **6** (FIG. **1**) does not cause energy to flow from one system to the other, since the wave filters function independently of whatever bodies are situated in the doorway **6** (FIG. **1**). On the contrary, the geometric arrangement of coils is sensitive to the presence of electrically conducting bodies in the doorway **6** (FIG. **1**) and the favorable results which is achieved by making these coils **32, 35,** and **38** (FIG. **4**) perpendicular are partly destroyed whenever a large electrically conducting body passes through the outgoing doorway **6** (FIG. **1**).

I turn now to FIG. **6** which illustrates the plan comprised in a general way in the foregoing discussion. In FIG. **6,** for simplicity I illustrate one common radiating and receiving means **41,** and only one, since this shows the flexibility of my modified plan most clearly. In the block diagram, the user will note that there are provided three distinct wave filters, each connected at its input to a separate electrical entity. The electrical entity to which the first two wave filters are connected is in each instance an oscillator. For convenience, the filters **42** and **43** are also designed by the symbol F_1 and F_2 to indicate the center of a pass band which each of the said filters **42** and **43** selectively transmits. The third filter **44** is designated by the symbol $F_1 - F_2$ to indicate the fact that the center of its pass band is chosen at the difference frequencies corresponding with the difference between the two frequencies F_1 and F_2. The filters in question are deliberately taken from designs which permit extremely strong selectivity and extremely high exclusion of the unwanted frequencies.

As an example of a frequency corresponding with a capability of extremely strong filtering, F_1 may be 31 kilohertz, F_2 may be 21 kilohertz, and $F_1 - F_2$. 10 kilohertz. These frequencies can be very stringently filtered against one another and, in fact, exclusivity can be achieved to whatever extent is required. I therefore indicate these entities as being each connected to a single electronic device in the doorway detecting and energizing system **41.** A suitable doorway sensing and detecting device **41** adapted for the purpose is a flat wound coil **41** diagrammatically shown in FIG. **6.** Such a flat wound coil serves effectively because the two input energy sources **46** and **47** cause a concurrent influence on the contraband at the frequencies F_1 and F_2 whenever a contraband element has a significant component of its vector θ in a direction not in the plane of the coil. In a completely reciprocal manner, the illustrated doorway coil **42** is able to receive energy at the difference tone $F_1 - F_2$ with good efficiency, and can do so whenever the contraband marker element **2** (FIG. **1**) exhibits an appreciable component perpendicular to the plane of the doorway (shown in FIG. **6**) (at the time the contraband element **2** (FIG. **1**) is passing through the plane of the said doorway).

I refer again to FIG. **6.** In this figure it will be noted that there is provided two frequency sources F_1 and F_2, and two filter systems. It is obvious that if the frequency sources which deliver energy at F_1 and F_2 are adjusted so that the frequency $F_1 = F_2$, and furthermore, if I impose the requirement that these two alternating current energy sources be in phase, then, in this degenerate case, the entire system comprising the frequency sources delivering energy at the two frequencies F_1 and F_2 has the same effect as one oscillator and one filter. Accordingly therefore I achieve the same result if I simply omit the filter F_1 and the oscillator **46.** In a system comprised by such an omission, since $F_1 = F_2$, the quantity $F_1 - F_2$ has no significance as alternating current for the reason that $F_1 - F_2$ equals zero. However, in modulation products, as has been stated earlier, one of the functions that is generated is $F_1 + F_2$. For the case in which $F_1 = F_2$, $F_1 + F_2$ is of course 2F.

In the modification of the system which I am now describing with the help of FIG. **6**, the oscillator **46** and the filter **42** are omitted. I provide the substitution of a filter adapted to pass the frequency $2F_1$ instead of a filter **44** (as illustrated) to pass the frequency $F_1 - F_2$. The recognition of contraband marked merchandise by this modified system is identically the same as has been described in other embodiments of my invention. As will be later described, this single frequency system is particularly useful with the marker element shown in and described in conjunction with FIG. **7.** From an engineering standpoint it is required that the filter **43** of FIG. **6,** be adapted to particularly stringent rejection of the frequency 2F. In a lattice filter designed for single frequency rejection elimination of the unwanted frequency $2F_1$ from the output of this filter can be accomplished to more than 100 decibels in two meshes, providing the stability of the frequency of the oscillator **47** is sufficiently good. This is easily arranged by employing crystal control to stabilize the oscillator **47.** I envision the use of a temperature insensitive cut of the quartz crystal and, if necessary, I employ a temperature controlled environment to further improve the frequency stability of the oscillator **47.** The stability of oscillators has been controlled within one part per billion over long periods by the careful use of these techniques. Since I do not need such extreme frequency control, the adequacy of the methods which I propose is quite obvious.

In the use of my anti-shoplifting systems there is a problem of communicating the warning signal indicating that merchandise is being stolen, and bringing the indication to the attention of security guards who are not, necessarily, at the same place. To make this procedure convenient in finished buildings where the wiring is already in place, I propose the use of ordinary carrier frequency signaling techniques that are well known in the art, and propose that the carrier frequency signals be inserted on the electric power system.

Since my warning devices are electrically powered, it is convenient to insert the carrier warning signal on the cord through which the power requirements of the system are served, making communications connections of a separate nature unnecessary. The electronic equipment necessary to put the carrier frequency warning message into the power cord will generally be a part of, or will be situated close to the other parts of the anti-shoplifting system. In fact all these things may be on the same panel rack or may be built up in the same stack of shielded boxes, as proves convenient. I visualize such carrier frequency systems as a valuable and useful feature in combination with the other elements of my invention. In FIG. 6, the carrier frequency module is, as desired, the element **48.**

In FIG. 6 the operator will note that there are six electrical connections, comprising three pairs, going from the systems: (a) **46** and **42,** (b) **47** and **43,** and (c) **48** and **45.** U.S. Pat. No. 2,520,677 (Aug. 29, 1950) makes a similar use of six wires in the form of three pairs, and provides an especially effective means for filtering out the noise from the signal frequency $F_1 \pm F_2$, ($F_1 = F_2$, is used in the discussion in this patent application). I contemplate the use of all the same means and methods for improving the signal to noise ratio in this anti-shoplifting system, and employ the same in combination with the other features of my anti-shoplifting system to better reject unwanted noise and electrical disturbances of all kinds.

I refer once more to FIG. 6, and particularly I employ the device of FIG. **6** with the omission of elements **43, 44, 45, 47,** and **48.** I further describe the filter F_1 (element **42**) as a non-significant component comprised in this use of my FIG. **6** device as simply a pair of wires going straight through from left to right. In effect I omit the function of this filter. In this use of the FIG. 6 device I also construe the oscillator **46** as one emitting relatively very strong electrical oscillations, and one which may at times be adjusted or at least have its frequency reset to another value as required. Further the oscillator **46** may be a "warble" oscillator adapted to cyclically retraverse a small range of frequency.

In the use which I am now describing for the FIG. 6 device, I insert the coil identified in FIG. 6 as "doorway" at the point shown for the device 4 in FIG. **1.** The coil **41** is asumed to be taken to a proper scale so that it will fit in the space provided at location 4 in FIG. **1.** My FIG. **6** device so arranged is, in fact, suitable to perform the deactivating function. To assure the upward radiation of a strong electromagnetic effect through the belt **2A** of the checkout stand **3** shown in FIG. **1,** I arrange the design of the checkout stand so that there are no closed metallic loops between the device **4** and the merchandise **1** with contraband marker **2.** I further designate that the plane of my FIG. **6** coil **41** will be the same as the plane of the largest side of the box shaped space deignated at numeral **4** in FIG. **1.** For this use, and for all the other uses of the FIG. **6** device, it is understood that the mechanical coil support which is illustrated in FIG. **6** is an electrically non-conducting material, and a non-ferromagnetic material.

A preferred embodiment of a marker element is shown in FIG. **7.** The marker comprises an extremely favorable high permeability ferromagnetic material, as for example, a substance having a maximum permeability of 400,000 or thereabouts and a coercive force of 0.02 oersteds. The marker is provided with a very slender cross-section compared with length, as for example a cross-sectional area of 0.0004 square centimeters, and a length of 4 centimeters or more, the same being comprised in a ribbon not thicker than 0.00125 centimeters thick. The marker in the preferred embodiment is thus provided with a ratio of lengths to square root of cross-sectional area which exceeds 200. If such a contraband marker element is presented with its axis approximately parallel to the oscillating magnetic field in a doorway such as is illustrated in FIG. **1,** the oscillating magnetic field having an intensity of the order or magnitude of three oersteds (such a contraband element, being generally similar to element **9** in FIG. **2** and comprised of for example, as previously noted, of superpermalloy) the magnetic element so chosen returns harmonic frequencies of a very high order, extending up to and including 1.6 megacycles when excited by a frequency such as sixty cycles per second. Such harmonic frequencies reflected by the marker art thus in excess of the 20th order of the fundamental frequency.

Referring now to FIG. **8,** the reflected waveform from the marker shown in FIG. **7** is illustrated. When the marker **49** is present in the interrogation zone of the invention, the reflected waveform output consists entirely of odd harmonics of the power frequency of sixty cycles. As may be seen from FIG. **8,** the odd harmonics are present in evenly spaced alternating cusps. This conclusion is particularly rigorous for the case in which the loop antenna which receives the energy is chosen with a very insufficient number of turns and produces in an approximately rigorous manner an electrical voltage proportional to the time derivative of the surface integral of the magnetic flux threading through the loop antenna.

For a particular sensing system and a particular frequency of the cyclically reversing magnetic field, this time derivative will depend on the change in magnetic moment of the element. If the magnetization in the element is reversing in each half cycle, the magnetic moment of the saturated element itself is the upper limit of this change. The magnetic moment of a piece of ferromagnetic material can be determined from the well known relationship.

$$B = \mu H = H + 4 \pi m/V$$

where B is the magnetic induction, μ is the permeability, H is the applied field, m is the magnetic moment of the element, and V is its volume, i.e., the product of its cross-section and length. For a square loop material such as permalloy the maximum permeability occurs near the coercive force. Thus from the previous marker example, one can substitute values for permeability, coercive force, length, and cross-section to show that the magnetic moment change is approximately one electromagnetic unit (e.m.u.) or pole centimeter of magnetic moment. With the present apparatus, detection across a usefully wide exitway is possible with only 0.1 e.m.u. of magnetic moment change. The loop antenna may be element **5B** of FIG. **1,** for example.

In the use of the contraband elements of the particularly advantageous type which we have described, we employ the arrangement shown in FIG. **9** for the electronic energizing and readout at the doorway. In this use of the previously described FIG. **6** arrangement, we omit elements **42** and **46**, energizing the doorway with but a single frequency. The element **44** which has been hitherto characterized as a wave filter, we characterize instead in FIG. **9** as an electronic device **44'** for selecting even and odd harmonics present on the ingoing leads to element **44'**. The device **44'** in this arrangement delivers a voltage proportional to the ratio of the selected even and odd harmonics on the wires going out to amplifier element **45'**. In such a manner of use, the FIG. **9** device and the doorway coil **41'** illustrated in connection with it, serve to energize the security readout system and communications system **48'** (which relies on the output of the amplifier **45'**) for the purpose of energizing alarms, lighting lights, etc.

In addition to the use of the systems and apparatus disclosed herein as an anti-shoplifting means, the invention may equally well be utilized in various arrangements for classification, recognition on production lines, security, and for identification of objects such as I.D. cards, cancelled tickets, and other such similar applications.

Whereas the present invention has been described with respect to specific embodiments thereof, it will be understood that various changes and modifications will be suggested to one skilled in the art, and it is intended to encompass such changes and modifications as fall within the scope of the appended claims.

What is claimed is:

1. A system for sensing the passage of an object through a surveillance area comprising:

means for generating an oscillating magnetic field in said surveillance area,

an elongated thin open-stripe of ferromagnetic material for being secured to an object and having an aggregate saturation magnetic moment of about one pole-centimeter and producing at least one pulse of magnetic field having frequencies of very high order, extending up to and including the thousandth harmonic of the fundamental frequency of the oscillating magnetic field in response to a reversal of said field.

2. The marker of claim **1** wherein said generating means generates an oscillating magnetic field having a peak intensity of at least 3 oersteds.

3. A marker for use in a system for detecting the presence of an object within an interrogation zone wherein magnetic coils generate a magnetic field periodically varying at a predetermined fundamental frequency in the interrogation zone and a sensor operates a security readout upon detection of high harmonic frequencies of the fundamental frequency comprising:

a marker for being secured to an object to enable detection of the presence of the object within the interrogation zone,

said marker comprising an elongated thin ferromagnetic strip having a maximum permeability of in the range of 400,000,

said strip being about 4 centimeters in length and having a cross-sectional area of approximately 0.0004 square centimeters and a thickness not greater than about 0.00125 centimeters,

said strip when disposed with its longitudinal axis generally parallel to the varying magnetic field generating very high harmonic frequencies of the fundamental frequency for detection by the sensor.

4. The marker of claim **3** wherein said ferromagnetic strip is comprised of superpermalloy.

5. The marker of claim **3** wherein said fundamental frequency equals 60 cycles per second and wherein said strip returns harmonic frequencies extending to 1.6 megacycles.

6. A system for sensing passage of objects through a surveillance area comprising:

means proximate the area for producing oscillating electromagnetic energy components in the area,

a thin electromagnetically nonlinear marker having a magnetic permeability of at least 400,000 associated with each object and dimensioned to have a high ratio of length to cross-sectional area for reradiating electromagnetic energy at very high harmonic frequencies when said components are coupled to the marker, and

means for sensing electromagnetic energy in said area and for producing a signal in response to sensing energy re-radiated by a marker.

7. A system for detecting the presence of an object when said object is in an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency, said system comprising:

marker means to be secured to an object, said marker means comprising an elongated ferromagnetic element having a high permeability capable of generating signals containing harmonics of said fundamental frequency in excess of the 20th order when placed in said zone,

radiating means for producing within said interrogation zone said magnetic field having an intensity sufficient to reverse the magnetization of said ferromagnetic element while in said zone,

receiving means for detecting said signals containing said harmonics of said fundamental frequency produced by said ferromagnetic element, and

security readout and communications means coupled to said receiving means responsive to said signal to indicate the presence of an object in accordance with the harmonic content.

8. A system according to claim **7** wherein said marker element comprises a ribbon having a maximum permeability of at least 400,000 and a ratio of length to square root of cross-sectional area in excess of 200, wherein said marker element is positioned in the zone with its axis approximately parallel with the magnetic field, and wherein said radiating means for generating said varying magnetic field radiates into said interrogation zone a 60 Hz oscillating field having a peak intensity of at least 3 oersteds.

9. A system according to claim **7** wherein said radiating means for generating said oscillating magnetic field includes:

an oscillatory power source, and

a doorway coil comprising a flat wound coil to said power source to radiate an oscillating magnetic field into said interrogation zone, and wherein said receiving means comprises a loop antenna coupled to an amplifier, the output of which is coupled to said security readout and communication means.

10. A method for detecting the presence of an object when said object is in an interrogation zone having a magnetc field periodically varying at a predetermined frquency, comprising the steps of:

securing to an object a marker comprising an elongated ferromagnetic element having a high permeability capable of generating signals containing harmonics of said fundamental frequency in excess of the 20th order when placed in said zone;

radiating within said interrogation zone said magnetic field having an intensity sufficient to reverse the magnetization of said ferromagnetic element while in said zone;

receiving said signals containing said harmonics of said fundamental frequency produced upon reversal of the magnetization of said marker element when in said zone; and

energizing a security readout and communications system in response to said signals.

11. A method according to claim **10** wherein said ferromagnetic element is characterized by having a permeability in excess of 50,000, a coercivity of less than 0.1 oerstead, and dimensions such that the ratio of length to square root of cross-section area of said element is in excess of 150, and wherein said marker element is positioned in the zone with its axis approximately parallel with the magnetic field.

12. A method according to claim **10** further characterized by radiating within said interrogation zone said magnetic field having an oscillation frequency of 60 Hz, and a minimum peak intensity of at least 3 oersteds and further comprising receiving from said element said signals containing harmonics of said oscillating frequency extending up to and including those having a frequency higher than 10^{+6} Hz.

13. A system for detecting the presence of an object within an interrogation zone comprising:

coil means extending around said interrogation zone,

an oscillator having a fundamental frequency connected to said coil means,

marker means for being attached to an object to reflect harmonics of said fundamental frequency when said object is placed in said interrogation zone,

circuit means connected to said coil means for detecting even and odd harmonics present on said coil means and for generating a voltage representative of the ratio of selected even and odd harmonics, and

means responsive to said voltage for energizing object indication means.

14. A marker for being used in a system for sensing passage of objects through an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency comprising:

a marker for being secured to an object to be detected by said system,

said marker comprising an elongated thin ferromagnetic element of high permeability and characterized by dimensions including a ratio of length to square root of cross-sectional area of at least 200 such that said marker generates detectable signals containing harmonics of said fundamental frequency in excess of the 20th order when said object bearing said marker is placed in said zone with the longitudinal axis of said ferromagnetic element positioned generally parallel to the varying magnetic field.

15. A marker for being used in a system for sensing passage of objects through an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency comprising:

a marker for being secured to an object to be detected by said system,

said marker comprising an elongated thin ferromagnetic element of high permeability and characterized by a saturation magnetization in excess of 0.1 pole-centimeter such that said marker generates detectable signals containing harmonics of said fundamental frequency in excess of the 20th order when said object bearing said marker is placed in said zone with the longitudinal axis of said ferromagnetic element positioned generally parallel to the varying magnetic field.

16. A marker for being used in a system for sensing passage of objects through an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency comprising:

a marker for being secured to an object to be detected by said system,

said marker comprising an elongated thin ferromagnetic element of high permeability and having a cross-sectional area of less than 10^{-3} CM^2 and a length of at least 4 centimeters such that said marker generates detectable signals containing harmonics of said fundamental frequency in excess of the 20th order when said object bearing said marker is placed in said zone with the longitudinal axis of said ferromagnetic element positioned generally parallel to the varying magnetic field.

17. A marker for being used in a system for sensing passage of objects through an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency comprising:

a marker for being secured to an object to be detected by said system,

said marker comprising an elongated thin ferromagnetic element of high permeability and having a cross-sectional area of in the range of 0.0004 CM^2 such that said marker generates detectable signals containing harmonics of said fundamental frequency in excess of the 20th order when said object bearing said marker is placed in said zone with the longitudinal axis of said ferromagnetic element positioned generally parallel to the varying magnetic field.

18. A marker for being used in a system for sensing passage of objects through an interrogation zone having a magnetic field periodically varying at a predetermined fundamental frequency comprising:

a marker for being secured to an object to be detected by said system,

said marker comprising an elongated thin ferromagnetic element of high permeability and low coercive force and having a slender cross section compared to length, said marker further having a magnetic moment of a magnitude such that said marker generates detectable signals containing harmonics of said fundamental frequency in excess of the 20th order when said object bearing said marker is placed in said zone with the longitudinal axis of said ferromagnetic element positioned generally parallel to the varying magnetic field.

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