Oct. 3, 1967 C. F. BURNEY 3,344,629

ELECTRONIC LOCK WITH INDUCTIVELY COUPLED TUNED KEY CARD

Filed May 2, 1966 3 Sheets-Sheet 1

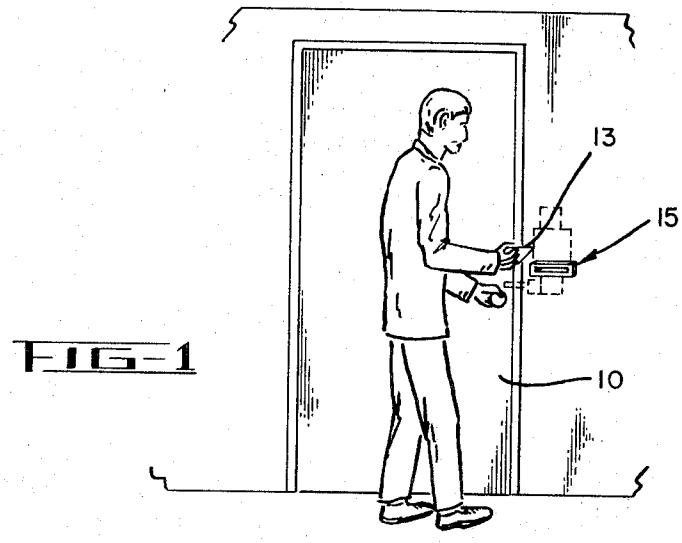


FIG-1

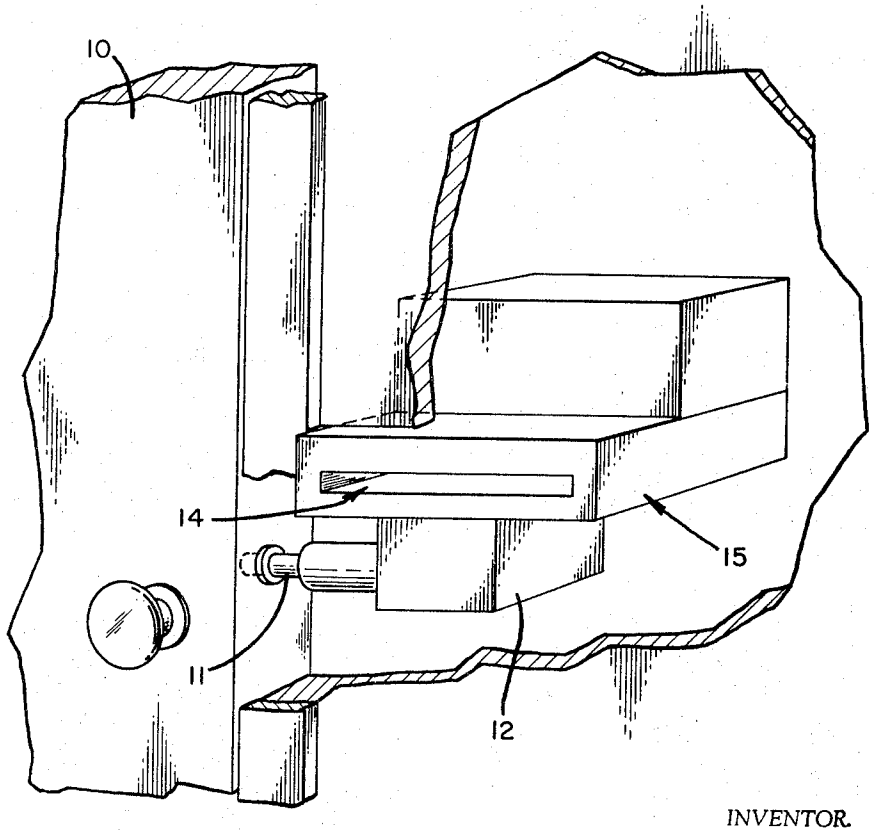


FIG-2

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Filed May 2, 1966 3 Sheets-Sheet 2

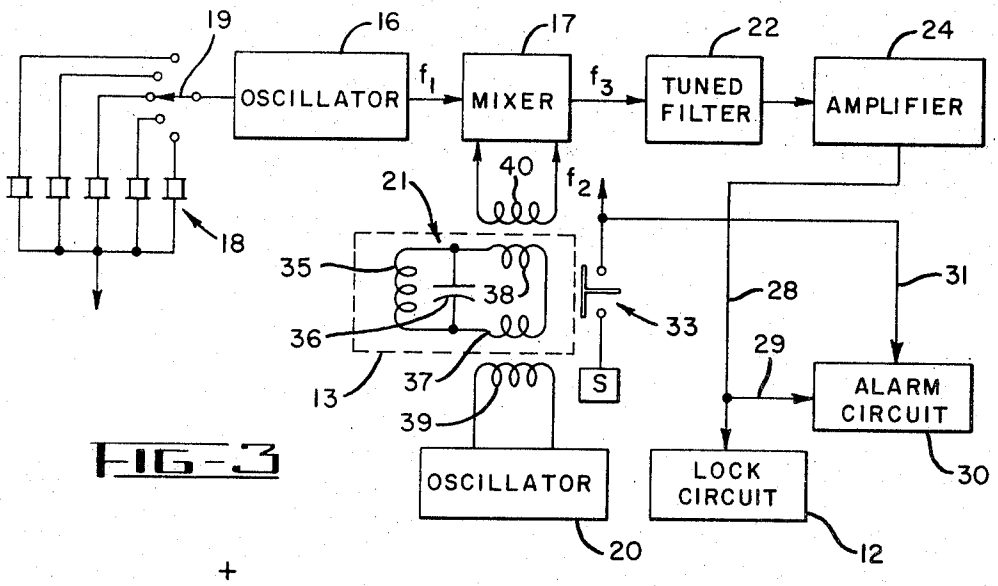


FIG-3

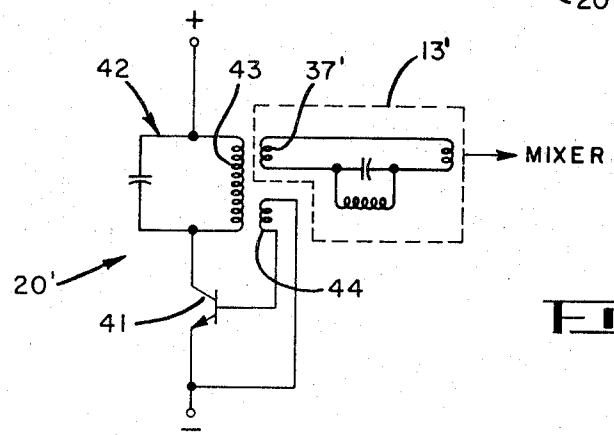


FIG-4

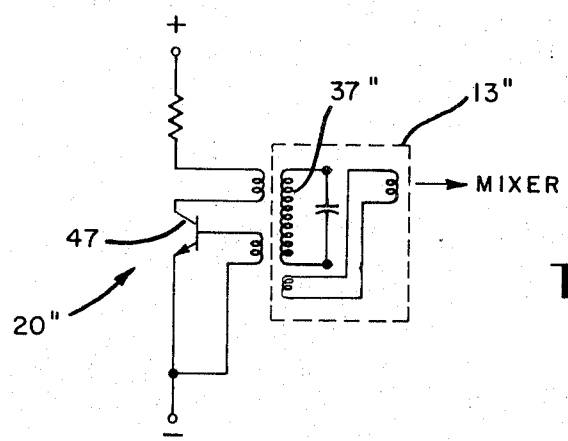


FIG-5

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ELECTRONIC LOCK WITH INDUCTIVELY COUPLED TUNED KEY CARD

Filed May 2, 1966 3 Sheets-Sheet 3

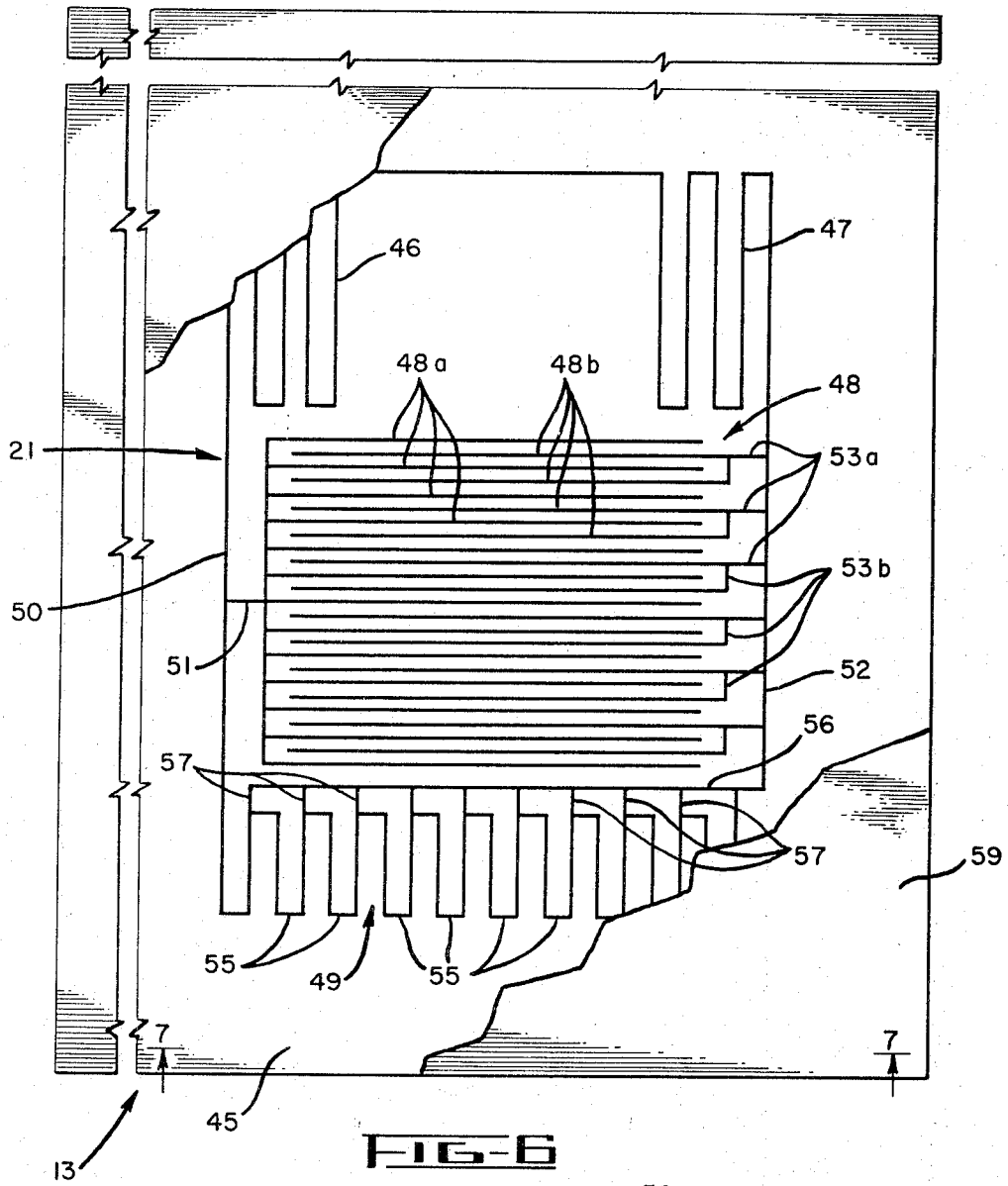


FIG-6

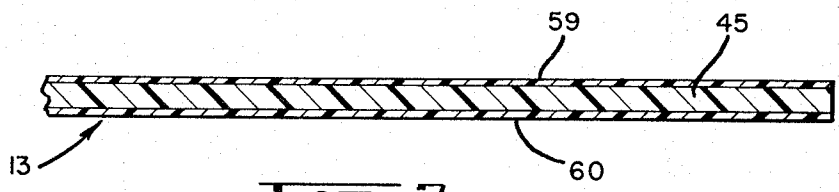


FIG-7

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United States Patent Office 3,344,629
Patented Oct. 3, 1967

3,344,629

ELECTRONIC LOCK WITH INDUCTIVELY COUPLED TUNED KEY CARD

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Filed May 2, 1966, Ser. No. 547,020
3 Claims. (Cl. 70—280)

ABSTRACT OF THE DISCLOSURE

A door lock is opened by a printed circuit pass card when inserted in a slot to inductively couple the output of one of two oscillators and the input to a mixer. A narrow passband filter at the output of the mixer discriminates against all frequencies except that produced by a valid pass card. An alarm circuit energized through a switch closable by the card in the key slot is disabled only by the filter output, thus providing an alarm if an invalid card is used. Printed inductors and capacitors on the card are so arranged that the tuning characteristic of the card is selectively changeable by punching the card.

This invention delates to an improved electronic locking system.

A lock system generally comprises a portable coded key and a lock actuator programmed to function when the key is inserted into it. In an electronic locking system, the inserted key, which may take the form of a card, affects the operation of an electrical circuit so as to actuate the lock mechanism. An example of the latter is the system described in Patent No. 2,779,874 in which the key card forms part of a multielement capacitor in the circuit. The inherently critical spacing between capacitor plates imposes severe limitations on positioning of the card in the slot. Also, reduction of the physical size of the key card for convenience of the user is limited by the necessity of providing the required capacitor plate area to operate the system in several coded modes.

An object of this invention is the provision of a highly selective electronic locking system capable of effectively discriminating against spurious signals or conditions that may tend to open the lock.

A further object is the provision of a locking system operated by a wallet-size key card that is readily programmable for one of a large number of key combinations and yet is extremely difficult to duplicate.

A further object is the provision of such a system which is operated by an easily insertable key card with a minimum wear on the parts.

Still another object is the provision of a lock system having a conveniently small printed circuit key with a capacity for a large number of easily programmable code combinations.

A more specific object is the provision of a frequency-coded electronic lock system.

A further object is the provision of a locking system which responds with an alarm to an attempt to defeat the system.

These and other objects of the invention are accomplished with a locking system in which a coded radio frequency (RF) signal is mixed with a reference RF signal and the output is monitored to either actuate the lock or an alarm. The frequency of one of the two signals from the RF sources is determined by a tuned circuit, preferably printed on a key card and inductively coupled into the system when inserted into the key slot of the locking system. The key card is opaque to hide the tuned circuit thereon which has interconnected capacitance and inductance

elements with values selectively predetermined as by external or internal punching of the card. The lock mechanism may be preset to one of many different code combinations by change of the inductance or the capacitance (or both) on the card, by adjustment of frequency generators and monitor, or by a combination of these changes. The inductance coils on the card connect to the tuned circuit and are positioned to effect inductive coupling of the card circuit to the fixed circuit of the system.

Other objects of the invention become apparent from the following description of a preferred embodiment thereof reference being had to the accompanying drawings in which:

FIGURE 1 is a schematic representation of a person seeking admittance through a doorway protected by a looking system of the type embodying this invention;

FIGURE 2 is a greatly enlarged view of part of FIGURE 1 with a wall broken away to show the position of the parts of the locking system;

FIGURE 3 is a block diagram of the circuits comprising the locking system;

FIGURES 4 and 5 are schematic diagrams of oscillators and key card circuits which may be utilized in the practice of the invention;

FIGURE 6 is a plan view of a key card with the opaque or circuit obscuring substance removed to show the printed configuration; and

FIGURE 7 is a section taken on line 7—7 of FIGURE 6.

Referring now to the drawings, an embodiment of the invention is shown in FIGURES 1 and 2 in conjunction with a door **10** which is locked and unlocked by a retractable bolt **11** adapted to project into the side of the door. Bolt **11** is moved between locking and unlocking positions by actuator **12**, such as a solenoid which is energized in a manner described below when a key card **13** is inserted in a slot **14** of the mechanism **15** mounted next to the door. Such a locking system is especially useful to control access to classified areas, private clubs, and the like, but it should be understood that these are merely a few of many examples of the way in which the invention may be practiced.

A schematic block diagram of a preferred embodiment of the invention is shown in FIGURE 3 and comprises an RF oscillator **16** having an output with a frequency f_1 connected to a mixer **17**. Frequency f_1 of oscillator **16** may be selected by connection of one of a bank of crystals **18** to the rest of the oscillator circuit by a switch **19**. A second input to mixer **17** has a frequency f_2 and is provided by another RF oscillator **20** having a frequency-determining circuit which includes a tuned circuit **21** wholly contained within card **13** and inductively coupled to the mixer. Thus, the frequency of RF energy generated by oscillator **20** is determined by the parameters of tuned circuit **21** which therefore controls the frequency f_2 of second input to mixer **17**.

The output of mixer **17** contains, inter alia, a signal having a frequency f_3 equal to the difference of the input frequencies to the mixer and is fed through a tuned filter **22** having a narrow bandpass characteristic set to pass only the difference frequency output from mixer **17** produced by a valid key card **13**.

The output of filter **22** passes to an amplifier **24** and is connected by line **28** to lock actuating circuit **12** and also by line **29** to alarm circuit **30**. An output signal on line **28** energizes lock circuit **12** to cause bolt **11** to be withdrawn from the door for unlocking it.

Alarm circuit **30** is connected by line **31** to a source S of power through a normally open switch **33** which preferably is so located in slot **14** of lock mechanism **15** that card **13** must be fully inserted in the slot to close the switch. When switch **33** is closed, alarm circuit **30** is pre-

conditioned so as to be ready to give an alarm. If a signal, called an inhibit signal, is applied to the alarm circuit from amplifier **24** via line **29**, the circuit **30** is not activated and no alarm is given. On the other hand, if no output comes from the amplifier, the alarm circuit is not disabled and the signal on line **31** produces an alarm. Switch **33** also serves to connect power source S to other elements of the circuit which are therefore preferably normally deenergized except when an attempt is made to open the lock.

Card **13** has a self-contained tuned circuit comprising a parallel-connected inductor **35** and capacitor **36** together with inductive coupling coils **37** and **38** which couple the card circuit to oscillator output coil **39** and mixer input coil **40**, respectively.

There are two codable subsystems in this locking system, the card **13** and the frequency components comprising oscillators **16** and **20** and tuned filter **22**. The whole locking system may be programmed through selection of the characteristics of either subsystem or both. For example, the frequency f_1 of oscillator **16** might be determined by selection of a particular crystal via switch **19** and filter **22** thereafter adjusted to pass the particular frequency f_3 produced by mixing of frequency f_1 with frequency f_2 from a valid key card circuit. Alternatively, the input frequency f_2 to the mixer might be changed by adjustment of oscillator **20** or by changing the parameters of the tuned circuit on the card as will be explained in greater detail below in conjunction with the description of the card circuit shown in FIGURE 6. The permutations and combinations of these several variables provide an extremely large number of potential codes which are readily and conveniently established by simple tuning procedures.

The locking system is programmed to respond to a key card **13** having a tuned circuit with predetermined parameters by selection of an operating frequency for oscillator **16** with crystal selector switch **19**, adjustment of the frequency of oscillator **20**, and by adjustment of the bandpass of filter **22**, preferably by tuning of the filter. All circuits of the system are normally deenergized, being disconnected from the power source by normally open switch **33**. In order to open the locked door, card **13** is inserted into slot **14** until it bottoms against switch **33** to close it and energize the circuits. The width and height of slot **14** is slightly greater than the width and thickness, respectively, of card **13** so that the latter may be freely guided into the slot without obstruction and yet is in proper position when bottomed therein so that card coupling coils **37** and **38** are in full energy transfer relationship with coils **39** and **40**, respectively.

The tuned circuit of card **13** becomes a part of the oscillator **20** so that the frequency f_2 of the signal on mixer input coil **40** is dependent on the parameters of the card circuit. The input signal to the mixer from oscillator **16** and the signal on coil **40** are mixed or heterodyned in mixer **17** and produce a signal at the mixer output with a frequency f_3 equal to the difference between f_1 and f_2. The pass band of filter **22** is selected to move pass signals having a frequency f_3 to amplifier **24**. All other frequencies are rejected by filter **22** and therefore produce no output from the filter.

The signal passed by filter **22** produces an output from amplifier **24** to line **28** which energizes a lock circuit **12** to withdraw bolt **11** from the door. Alarm circuit **30** is also conditioned by input on line **31** from power source S to give an alarm but is prevented from doing so by the inhibit signal from amplifier **24** on line **29**.

In the event an invalid card or other device is inserted in slot **14** sufficiently to depress and close switch **33**, the output of mixer **17** is such that no output is produced by amplifier **24** either to energize the unlocking circuit **12** or to prevent circuit **30** from giving an alarm. Thus, an attempt to defeat the system is immediately identified to facilitate corrective action and to discourage further tampering.

Various types of RF oscillators **20** may be utilized in practice of this invention. Similarly, the inductive coupling of energy from oscillator **20** into the tuned circuit **21** of key card **13** may be accomplished in different ways, as long as the card circuit forms a part of the circuit which determines the output frequency of oscillator **20**. By way of example, oscillator **20'** shown in FIGURE 4 may comprise a transistor **41** with a tank circuit **42** having an inductance **43** which is coupled both to input coupling **37'** of card **13'** and to feedback coil **44** of the transistor. Alternatively, oscillator **20''** shown in FIGURE 5 comprises a transistor **47** with emitter and collector inductively coupled together and to the resonant circuit of card **13''** by coil **37''** on the card.

In accordance with the invention, key card **13** comprises a layer of synthetic material **45**, see FIGURE 6 and 7, which is pervious to RF energy and on which the tuning circuit **21** preferably is printed by well-known printed circuit techniques. The circuit is generally rectangularly configured with loops **46** and **47** comprising the input and output coupling coils located at the top corners, as viewed, and connected in series with each other and in parallel with a group **48** of line capacitors and with a bank **49** of inductance loops. The capacitor group consists of a plurality of closely spaced parallel lines, of which alternate lines **48***a* are connected to trunk **50** by a common connection **51** and the remaining parallel lines **48***b* are connected to trunk **52** by line connections **53***a*. Also, lines **48***b* are grouped in successive pairs with the lines of each pair connected together by a line connection **53***b*. The bank of inductors comprise individual rectangular loops **55** formed in electrical series with each other and connected in parallel with a cross trunk **56** by connections **57**. Trunks **50**, **52**, and **56** are connected in series. Both sides of layer **45** may be covered by opaque, RF pervious layers **59** and **60** permanently bonded thereto, and which not only hide the circuit **21** but also provide a means for carrying appropriate legends, titles, or other messages useful to the purpose of the card. Alternatively, the card may comprise two layers of opaque material sandwiched together and permanently sealed with the tuned circuit on the inside.

In the form shown in FIGURE 6, circuit **21** has maximum capacitance since all "plates" (lines) of the capacitors are connected to the trunks **50** and **52**. The circuit has minimum inductance since all of the loops **55** are short-circuited by cross trunk **56**. In accordance with the requirements of the application, the magnitudes of inductance and capacitance of circuit **21** may be initially programmed and thereafter changed, as desired, by a simple external punching operation which selectively breaks one or more electrical connection at the capacitor and at the inductance loops. More specifically, capacitance may be decreased from a maximum in steps by punching the card so as to successively sever connections **53***b*, thereby removing one plate **48***b* with each such severing operation, or to cut connections **53***a* separately so as to remove a pair of plates **48***b* with each such operation. Conversely, trunk **56**, which short-circuits all of the inductance loops, may be successively cut by punching to increase the magnitude of inductance in the circuit from a minimum. Thus, each segment of trunk **56** between adjacent loop connections **57** may be selectively severed to connect the included inductance loop into the circuit. The permutations and combinations of codes available by such card punching are significantly large and yet the compactness of the circuit is conveniently adaptable to cards of wallet size or smaller.

It should be noted that the location of the punched holes does not necessarily indicate the magnitude of the capacitance or inductance in the circuit even with identically configured capacitor plates and inductance loops;

that is, one inductance is added to the circuit irrespective of which segment of trunk **26** is severed, and similarly a unit of capacitance is removed from the circuit for each punching of a connection **53***a* or **53***b*. Dummy holes may also be punched in a card to further disguise the card and enhance the security of the system.

Changes, modifications, and improvements to the above-described embodiment of the invention may be made by those skilled in the art without departing from the spirit and scope of the invention. For example, the circuit **21** on card **13** may initially be formed with predetermined inductance and capacitance values to give a coded frequency, and thus no external punch marks would appear on the card. Also, the card circuit may be formed by other than printed circuit techniques. The claims define essential features of novelty in the invention.

I claim:

1. A key card for an electronic locking system comprising

an electromagnetic wave-pervious electrically nonconducting sheet having a circuit formed thereon and covered by another like sheet,

said circuit comprising

a pair of inductive coupling coils connected in series,

a plurality of parallel line capacitor elements separately connected in parallel with said coils whereby a unit of capacitance is removed from said circuit for each of said connections that is severed, and

a plurality of series-connected inductance elements separately shunt-connected across said coupling coils whereby a unit of inductance is added to said circuit for each of said shunt connections that is severed.

2. A system for operating a lock comprising

a source of power,

electromagnetic wave generator means adapted to produce a signal having a predetermined frequency,

said generator means comprising fixed circuits and a key card having a self-contained frequency control circuit selectively positionable in an operative location adjacent to said fixed circuits to produce said predetermined frequency,

a normally open switch electrically connected between said power source and said fixed circuits and closable by the card in said operative location,

a filter responsive only to said signal for producing an output,

a utilization circuit responsive to the output of said filter for changing the operating state of the lock, and

an alarm circuit having one input connected to said power source through said switch and a second input responsive to the output of said filter for disabling the alarm circuit.

3. A system for operating a lock comprising

electromagnetic wave generator means adapted to produce a signal having a predetermined frequency,

said generator means comprising fixed circuits and a key card having a self-contained frequency control circuit selectively positionable in an operative location adjacent to said fixed circuits to produce said predetermined frequency, said generator means comprising

first and second oscillators having outputs with different frequencies, one of said oscillators including the circuit on said key card, and

means for mixing the output of said oscillators to produce said signal,

said card circuit comprising interconnected inductance and capacitance elements and coupling loops for inductively coupling said elements to one of the oscillators and to the mixing means,

a filter responsive only to said signal for producing an output, and

a utilization circuit responsive to the output of said filter for changing the operating state of the lock.

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