United States Patent [19]

Armstrong

[11] **3,831,162**

[45] **Aug. 20, 1974**

[54] **INTRUSION DETECTION AND LOCATION SYSTEM**

[75] Inventor: **John E. Armstrong,** Cupertino, Calif.

[73] Assignee: **GTE Sylvania Incorporated,** Mountain View, Calif.

[22] Filed: **Sept. 4, 1973**

[21] Appl. No.: **393,796**

[52] **U.S. Cl.** .... **340/261,** 340/16 R, 340/258 D
[51] **Int. Cl.** **G08b 13/16**
[58] **Field of Search** .... 340/16 R, 258 D, 261

[56] **References Cited**

UNITED STATES PATENTS

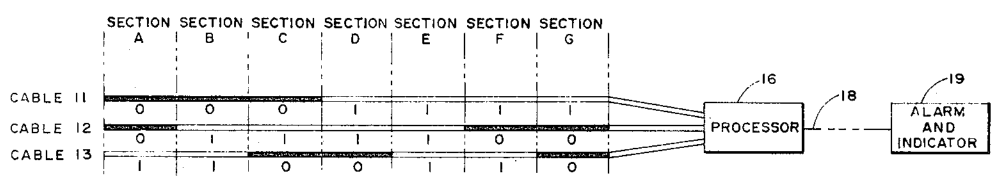
2,345,771	4/1944	Reynolds	340/261
2,435,996	2/1948	Baird	340/261 X
2,573,748	11/1951	Weinstein et al.	340/16 R
2,787,784	4/1957	Meryman et al.	340/258 D
3,109,165	10/1963	Bagno	340/258 D
3,132,330	5/1964	Donner	340/261 X
3,747,057	7/1973	Brougher	340/16 R
3,750,127	7/1973	Ayers et al.	340/261
3,763,482	10/1973	Burney et al.	340/258 R

Primary Examiner—David L. Trafton
Attorney, Agent, or Firm—John F. Lawler; Norman J. O'Malley; Elmer J. Nealon

[57] **ABSTRACT**

An intrusion detection and location system for perimeter protection comprises an elongated composite sensor line having a plurality of closely spaced coaxial electret cable transducers with known different sensitivities over their lengths and circuits responsive to electrical signals from the cables caused by mechanical vibrations applied to the cable by an intruder for producing an indication of the attempted intrusion and its location. Each of the cables has several longitudinal sections and laterally adjacent sections of the several cables have equal lengths and are respectively differently sensitized so that an intrusion occuring at one section generates in all the cables a binary coded output which uniquely identifies that section. In a preferred embodiment of the invention, the cable sections are either in a sensitized or non-sensitized state and the cables in successive sections are conditioned to produce a Gray code to minimize location errors for intrusions occuring at or near the junction of two sections. The cables are connected to processing circuits which decode the signals and transmit alarm and intrusion location information to the remote monitoring station.

7 Claims, 5 Drawing Figures



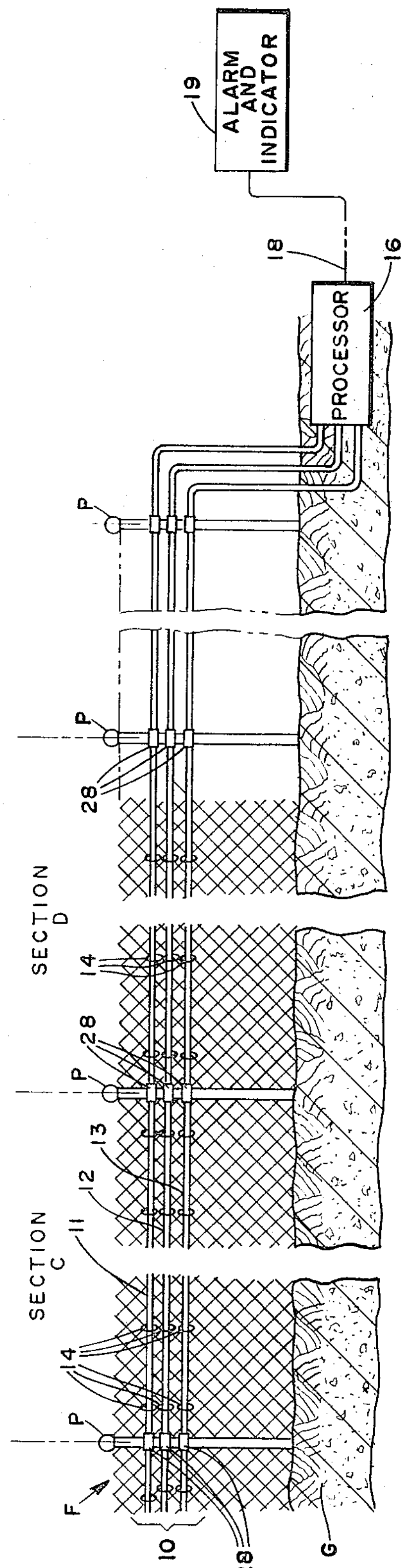


FIG. 1

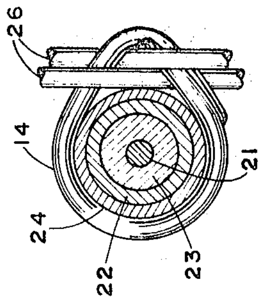


FIG. 3

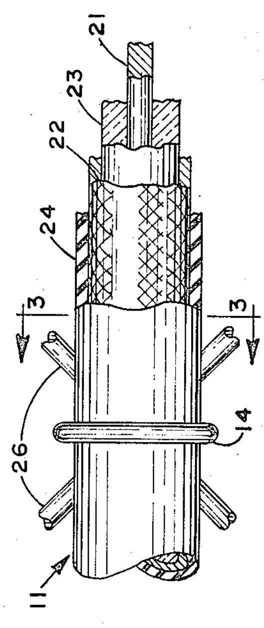


FIG. 2

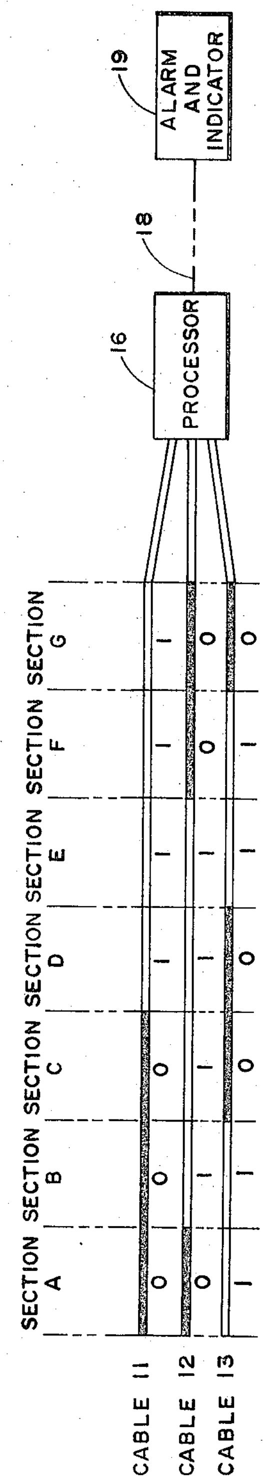


FIG. 4

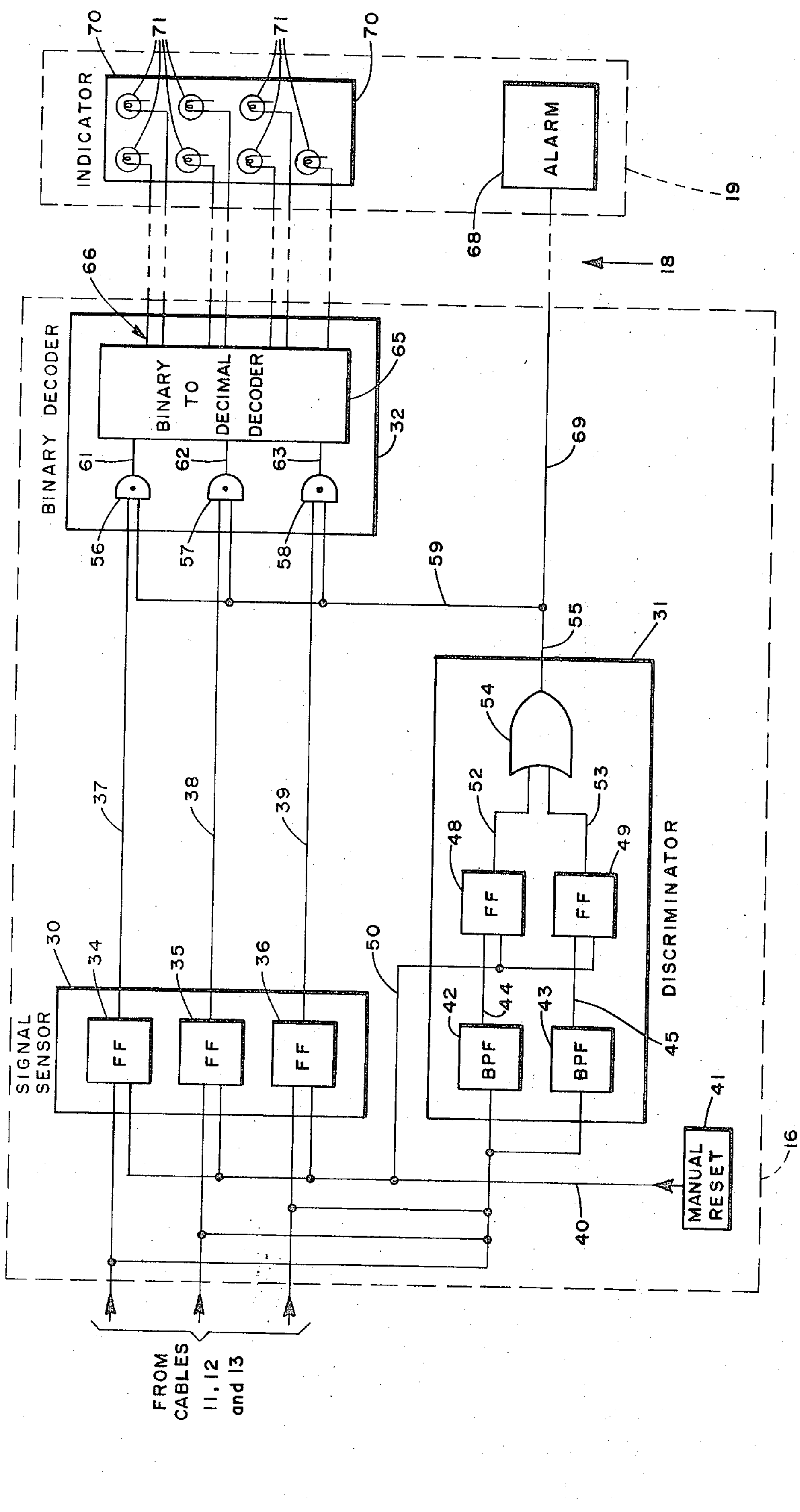

INDICATOR
ALARM
BINARY DECODER
BINARY TO DECIMAL DECODER
SIGNAL SENSOR
FF
FF
FF
DISCRIMINATOR
FF
FF
BPF
BPF
MANUAL RESET
FROM CABLES 11, 12 and 13

FIG. 5

INTRUSION DETECTION AND LOCATION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to intrusion detection systems useful in perimeter detection.

A perimeter-type intrusion detection system described in U.S. Pat. No. 3,763,482 utilizes a coaxial electret cable as a sensor line. The cable is tightly clamped to a chain link fence at intervals throughout its length and constitutes a continuous transducer for converting fence vibration that may be caused by intruders into electrical signals which are processed by appropriate discrimination circuits for activating remote alarm apparatus. While this system has proven to be extremely effective in detecting intrusions, there remains the problem of determining where the intrusion has occurred. With installations having fence perimeters that are several hundreds of meters or more in length, knowledge of even the approximate location of the intrusion is often vital to effective follow-up action in protecting the property that is threatened. This invention provides such location information.

A general object of this invention is the provision of an improved perimeter protection system which automatically indicates the location of the attempted intrusion along with an indication of the intrusion itself.

A further object is to provide such a system that is low in cost and is relatively inexpensive to install.

SUMMARY OF THE INVENTION

These and other objects of the invention are achieved with a plurality, preferably three or more, juxtaposed coextensive continuous transducers formed in several longitudinally successive sections and with each of the laterally adjacent transducer sections being differently sensitized according to a predetermined code unique to that section. By decoding the combined outputs of the three transducers, the system indicates not only the fact of an attempted intrusion but also the section of the cables at which it occurred.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation of a portion of a chain link fence to which coaxial electret cables embodying the invention have been connected;

FIG. 2 is an enlarged cut-away portion of one of the coaxial cables of FIG. 1 showing the fence mounted clamping rings;

FIG. 3 is a transverse section taken on line 3—3 of FIG. 2;

FIG. 4 is a schematic view of the system embodying the invention showing adjacent sections of sensitized and unsensitized cable for producing binary coded signals indicating the location of each of the several sections; and

FIG. 5 is a detailed schematic block circuit diagram of the signal processing and alarm/indicator circuits.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 illustrates a chain link fence F supported by posts P in the ground G and bordering an area to be protected. The fence comprises a plurality of longitudinal sections, two of the sections being indicated as C and D. If such a fence is equipped with a coaxial cable transducer system of the type described in U.S. Pat. No. 3,763,482, an alarm is given when an intruder attempts to climb the fence at any of the several sections of fence. While this protection may be sufficient for the particular requirement as when the risk of immediate damage to the protected area or items in it by intruders is not great, there are many applications when such risk is great so that additionally it is vital to know the location of the attempted intrusion. An example for such a need for intruder location information is a several acre storage area for portable property items that are subject to hit and run theft tactics. Another example is the oil and gas storage tank area for a refinery that may be the target for sabotage or vandals. In each case, information on the approximate location of the intrusion is necessary in order that prompt action may be taken for protection or recovery of the property.

In accordance with this invention, such intruder location information is obtained with the system comprising a composite sensor line **10** consisting of three coaxial cables **11, 12** and **13** which are mounted on fence F over the length of the protected area. It is understood that the fence mounted embodiment is given by way of example and not by way of limitation since the invention may be practiced also by burying the cables in the ground, disposing them under a floor or otherwise placing them across the protected area. Furthermore, the cables might be packaged in one sheath or sleeve to facilitate handling and installation. Cables **11, 12** and **13** are spaced closely together and are secured to the main body of the fence by clamp rings **14** so as to provide a tight mechanical coupling between the fence and cables. One of the adjacent ends of the cables is open while the opposite ends are connected to a signal processor circuit **16** illustrated in FIG. **1** as being buried in the ground G. Electrical output signals generated by the transducing action of the three cables in response to vibrations on the fence are processed by circuits **16** which eliminate false alarm signals and determine by a logic function to be described the location along the fence of the disturbance producing the signals. The output of circuit **16** is transmitted by line **18** to alarm and indicator apparatus **19** at a remote monitoring station; the alarm signifies that an intrusion is taking place and the indicator identifies the location of that intrusion.

The details of construction of cables **11** and **12** are explained in U.S. Pat. No. 3,763,482. Briefly, each cable, cable **11** for example, comprises an inner conductor **21,** see FIGS. 2 and 3, an outer conductor **22,** a dielectric filler **23** between these conductors and an outer synthetic insulating cover **24** on outer conductor **22.** Dielectric filler **23** is an electret and produces an electrical signal between conductors **21** and **22** when a mechanical force causes relative motion between the dielectric and the outer conductor of the cable. Each of the clamp rings **14** tightly secures the cable to the main body of the fence, shown in FIGS. 2 and 3 as strands **26,** so that vibrations induced in the fence by an intruder or the like climbing it cause a signal to be generated across conductors **21** and **22.**

The sensitivity of such a coaxial cable transducer is determined by the amount of charge on the electret filler **23.** One technique for making the electret as explained in the aforementioned patent is to apply a d-c potential of predetermined magnitude across the conductors **22** and **23** while the heat softened filler **23** cools and solidifies. The amount of charge on the filler generally varies proportionally with the magnitude of the applied d-c biasing voltage. The sensitivity of this electret cable as that term is used herein means the signal strength or voltage produced across the outer and inner conductors at one end of the cable per unit of impact force applied exteriorly to the cable.

The sensitivities of cables **11, 12** and **13** at various points throughout their lengths differ so that the sensitivity combination of the three cables at one such point is different from similar sensitivity combinations at all other such points. By varying the sensitivity combination of the three cables in this manner, the several longitudinally distributed points on the composite sensor line are provided with predetermined sensitivity codes which uniquely identify those points or locations, respectively. In a preferred form of the invention, the sensitivity of each cable varies between two levels, a high level of approximately 1 microvolt per micrometer of indention and a low level preferably at zero. It will be understood, however, that more than two sensitivity levels may be used to obtain a location code with slightly more sophisticated processing circuitry.

In the embodiment of the invention shown in FIG. **1,** each of cables **11, 12** and **13** is composed of a longitudinal series of cable sections detachably or otherwise connected together by connectors **28** located, for example, at fence posts P. Two such sections are designated as C and D in the drawing. The juxtaposed row of cables comprising each section have the same lengths and the pattern or combination of cable sensitivities varies from section to section in the predetermined manner described above. Thus the location of an intrusion with this cable arrangement can be made to the accuracy of one cable section.

When cables having two levels of sensitivity are used, the number of sensitivity-coded sections into which a protected boundary may be divided is determined by the number of cable transducers that are used in accordance with the expression

$$S = 2^N - 1 \quad (1)$$

Where S is the number of sections and N is the number of cable transducers. Thus a two-cable system permits division of the protected line into three sections ($S = 2^2 - 1 = 4 - 1 = 3$), a three-cable system yields seven sections, a four-cable system 15 sections and so on. If more than two sensitivity levels are used, the foregoing expression becomes

$$S = L^N - 1 \quad (2)$$

where L is the number of sensitivity levels. For example, a three-cable ($N = 3$) system with three sensitivity levels ($L = 3$) could produce 26 sensor line sections. The accuracy of the location data is therefore dependent upon the number of sensor cables and sensitivity levels that are used and this is dictated by the desired system resolution and cost. It should be noted that coaxial cable transducers of the type described above are relatively inexpensive per unit length and the increase in installation costs of four cables, for example, as compared to three cables is insignificant.

FIG. **4** illustrates seven sections A – G, inclusive, of cables **11, 12** and **13** with sensitivities varying between a zero level indicated in heavy line and designated by the binary digit "0" and a predetermined positive level indicated by the unshaded line and designated by the binary digit "1." Each of the seven sections of the cables has a sensitivity code which is different from the other sections so that the output signals from the three cables is a binary coded word which uniquely designates the particular section from which the signal was generated as by an attempted intrusion or other disturbance. By way of example, the binary word "001" generated by the three cables **11, 12** and **13** in that order designates Section A whereas the word "100" denotes Section G. This output of the cables is decoded in processor **16** and, if caused by an intruder, energizes alarm and indicator unit **19.**

An important feature of the invention is that the section coding arrangement is a Gray code. That is to say, the sensitivity pattern between any two adjacent sections is such that only one cable changes sensitivity. If an intruder should attempt to climb the fence at or near the junction of two sections so as to excite a sensitized conductor in both sections, the maximum location error generated is one section. For example, assume an intruder attempts to cross Section B near its junction with Section C. Since according to the Gray code only cable **11** changes its sensitization state, the code of "110" or Section C would be transmitted, thus limiting the error to within one section.

Processor **16** comprises a signal sensor **30,** see FIG. **5,** a discriminator **31** and a binary decoder **32.** Sensor **30** comprises bistable flip-flops **34, 35** and **36** having inputs connected to cables **11, 12** and **13** and outputs connected to lines **37, 38** and **39,** respectively. Each flip-flop of the sensor is also connected by line **40** to a manual reset mechanism **41.** Each of flip-flops **34, 35** and **36** produces a logic "0" on its output line until a signal is received from corresponding sensor cable and produces a logic "1" from the first instant such signal is received until the flip-flop is manually reset to produce a "0" by an input on reset line **40.** These flip-flops change state when an analog input from the respective sensor line rises above a preset value.

Discriminator **31** is designed to recognize characteristics of the analog signal produced by the coaxial cable sensors when produced by an intruder. By way of example, discriminator **31** is capable of recognizing and passing signals defining the signature of a man climbing or cutting the fence or digging under it. At the same time, this circuit rejects spurious signals such as those produced by wind, birds landing on the fence, cattle rubbing against the fence, etc. In its simplest form, sensor **31** comprises bandpass filters **42** and **43** connected to the outputs of cables **11, 12** and **13** in parallel with signal sensor **30** and having bandpass characteristics covering those parts of the frequency spectrum within which the signals of interest lie. The outputs of bandpass filters **42** and **43** on lines **44** and **45,** respectively, are connected respectively to flip-flops **48** and **49,** each of which produces a logic "0" output until a signal is received from the corresponding bandpass filter. As with the signal sensor circuit **30** described above, these flip-flops change to the "1" state upon receipt of a signal from the bandpass filter and remain in that state until reset by manual reset **41** to which they are connected by lines **40** and **50.** The outputs of flip-flops **48** and 49 on lines **52** and **53**, respectively, are combined in an OR gate **54** which produces on line **55** a single output, i.e., a logic "0," if no intruder is present and a logic "1" if an intruder is present.

While two channels only have been shown in discriminator **31**, more channels may be included for providing a more selective discrimination as required or desired. Similarly, additional discrimination may be provided with integration and threshold circuits as desired or required.

Binary decoder **32** comprises AND gates **56, 57** and **58** having inputs connected to signal sensor output lines **37, 38** and **39**, respectively, and to the output **55** of OR gate **54** via line **59**. The outputs of these AND gates on lines **61, 62** and **63**, respectively, are connected to a binary-to-decimal decoder **65** having a plurality of output lines **66**, seven as shown corresponding to the seven cable sections, respectively, shown in FIG. **4**. By way of example, decoder **65** may readily be derived from a Signetics N7442 decoder manufactured and sold by Signetics Corporation, Sunnyvale, Calif.

Remote unit **19** comprises an alarm unit **68** connected to the output line **55** of discriminator OR gate **54** by line **69** and an indicator **70** having a plurality of lamps **71**, seven for this embodiment, connected respectively to the outputs **66** of decoder **65**. Alarm unit **68**, which may be a bell, flashing light or the like is energized whenever an intrusion occurs and one of the lamps **71** of indicator **70** is energized to designate the one of the seven sections of the sensor cables at which the intrusion has occurred.

In operation, an intrusion occurring, for example, in Section D of the cables, see FIG. **4**, generates a "110" digital word on cables **11, 12** and **13**, respectively. The outputs from the cables to sensor **30** cause flip-flops **34** and **35** to change from the "0" state to the "1" state while the remaining flip-flop **36** is unchanged because the unsensitized portion of cable **13** generates no signal. This produces a digital word signal of "110" on signal sensor output lines **37, 38** and **39** as one input to AND gates **56, 57** and **58**, respectively, of binary decoder **32**. Simultaneously, discriminator **31** receives and processes the outputs from the cables and passes them if they meet the bandpass and other criteria for signals of interest, i.e., those generated by an intruder. The output from OR gate **54** of the discriminator energizes alarm **68** and provides the other of the two inputs to AND gates **56, 57** and **58** of the binary decoder. Thus the binary decoder is operative only if the signals on the sensor cables meet the established criteria for an intruder. The binary coded word "110" on AND gate output lines **61, 62** and **63**, respectively, is logically interpreted by decoder circuit **65** to energize the indicator lamp **71** which designates Section D of the sensor cables.

What is claimed is:

1. A disturbance detection system comprising

a plurality of elongated continuous transducers disposed along a boundary being monitored and adapted to produce output electrical signals in response to the mechanical force applied to the transducers,

said transducers being juxtaposed whereby a disturbance occurring at any location along said boundary applies a substantially equal force to all of the transducers,

each of said transducers comprising a plurality of sections in longitudinal series, laterally adjacent sections of said transducers being coextensive and having equal lengths and comprising rows,

the transducing sensitivity of the sections being in at least two different states whereby the combination of electrical output signals from the transducers caused by a disturbance represents a code,

the maximum number of sections of said transducers being given by the expression

$$S = L^N - 1$$

where S is the number of sections, N is the number of transducers and L is the number of sensitivity states,

the sensitivity codes for the sections being different whereby the composite signal output of said transducers contains information indicating both a disturbance along said boundary and its location,

means for coupling to said transducers mechanical forces produced by the disturbance to be detected,

means for processing the composite output signals from said transducers for producing an output signal designating the section of transducers at which the disturbance occurred, and

means responsive to said output signal from said processing means for giving an alarm and indicating the location of said disturbance.

2. The system according to claim **1** in which the pattern of variation of said sensitivity states of said sections of transducers is in accordance with the Gray code.

3. The system according to claim **1** in which $L = 2$, said processing means comprising

signal sensor means responsive to the outputs from said transducers for translating same into binary coded form and

binary decoder means for converting said binary coded signals into said section-designating output signal.

4. The system according to claim **3** in which said processing means also includes discriminator means responsive to the outputs of said transducers for passing signals of interest and rejecting other signals, producing an output only if the transducer outputs contain signals of interest, said binary decoder means being connected to said discriminator means and being enabled by said output of the latter.

5. A perimeter-type intrusion detection system comprising

a plurality of juxtaposed coaxial electret cables adapted to produce output electrical signals in response to mechanical vibrations produced by an intruder,

each of said cables comprising a plurality of sections in longitudinal series, laterally adjacent sections of said cables being coextensive and aligned in rows,

the transducing sensitivity states of the cable sections being characterized by a high level and a low level whereby excitation of a row of sections by an intruder produces a coded composite output signal from the plurality of cables corresponding to the sensitivity states of the sections in the row,

each row having a different section sensitivity pattern relative to the other rows whereby the code of said composite output signal is indicative of the excited row,

means for decoding said coded composite signal, and

means responsive to said decoded signal for indicating the excited section.

6. The system according to claim **5** in which the number of said cables is at least three.

7. The system according to claim **5** in which the value of said low sensitivity level is zero.

* * * * *