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# United States Patent [19]

Podhrasky

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[54] METAL DETECTOR HAVING TARGET CHARACTERIZATION AND SEARCH CLASSIFICATION

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[73] Assignee: Garrett Electronics, Inc., Garland, Tex.

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[22] Filed: Jun. 20, 1990

[51] Int. Cl.[5] ..... G08B 13/14

[52] U.S. Cl. ..... 340/572; 324/329; 340/691

[58] Field of Search ..... 340/572, 525, 691, 658, 340/825.7; 324/329; 364/516; 446/129

[56] References Cited

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| | | | |
|---|---|---|---|
| 4,334,191 | 6/1982 | Podhrasky | 324/329 |
| 4,507,612 | 3/1985 | Payne | 324/329 |
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| 4,700,139 | 10/1987 | Podhrasky | 324/329 |
| 4,868,910 | 9/1989 | Maulding | 324/329 X |

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"VLF 553D Detector", Fisher Research Laboratory, Issue VLF977, 1977.

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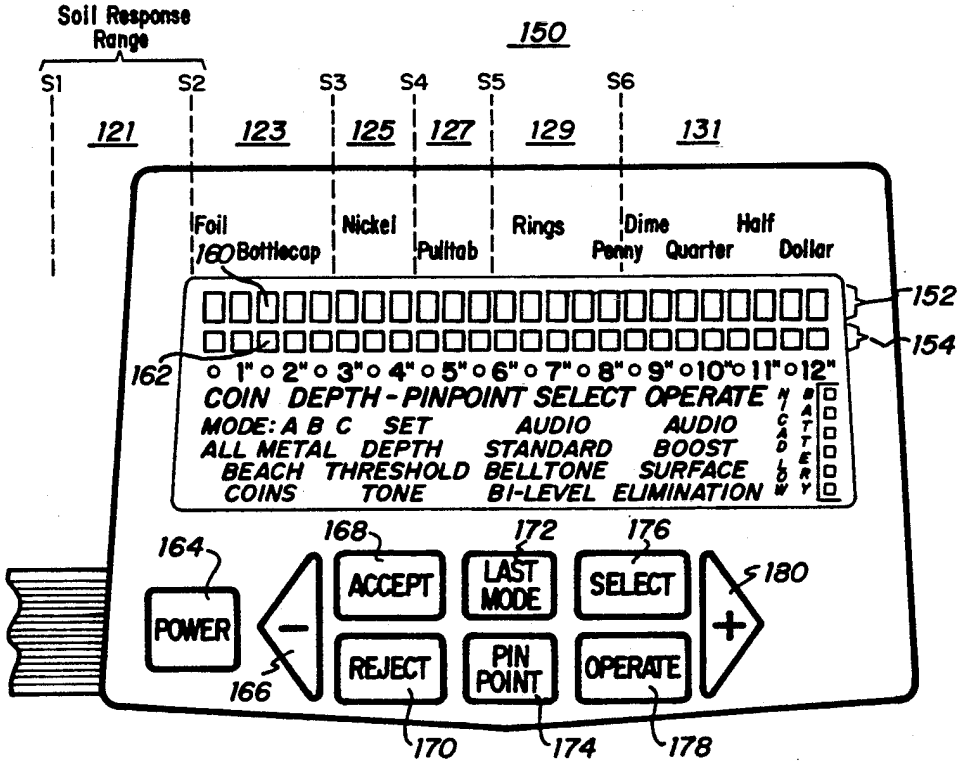
*Assistant Examiner*—Thomas J. Mullen, Jr.
*Attorney, Agent, or Firm*—Richards, Medlock & Andrews

[57] ABSTRACT

A metal detector is provided with circuitry for producing a plurality of vector signals derived from a target signal. Each of these vector signals corresponds to a phase characteristic of target signals. These vector signals define phase ranges which correspond to classifications of targets. Upon detection of a target signal, the metal detector generates first and second phase detected signals which in turn generate a plurality of vector signals. These vector signals are digitized and within a microprocessor a determination is made through slope analysis to determine which range includes the principal phase of the detected target signal. The vector signals which define the identified range are then utilized in algebraic calculations to define one of a plurality of subphase ranges within each range. This identified subphase range identifies a segment in a linear display which is illuminated to show the determined characteristic for the detected object. An operator can program the detector to select or reject target objects having certain electrical characteristics and this is likewise displayed to the operator. When the detector determines that a target signal has the same characteristics as selected by the operator, an audio output is generated. The display provided to the operator enables the operator to easily select or reject specific signal characteristics pertaining to certain types of targets.

7 Claims, 8 Drawing Sheets



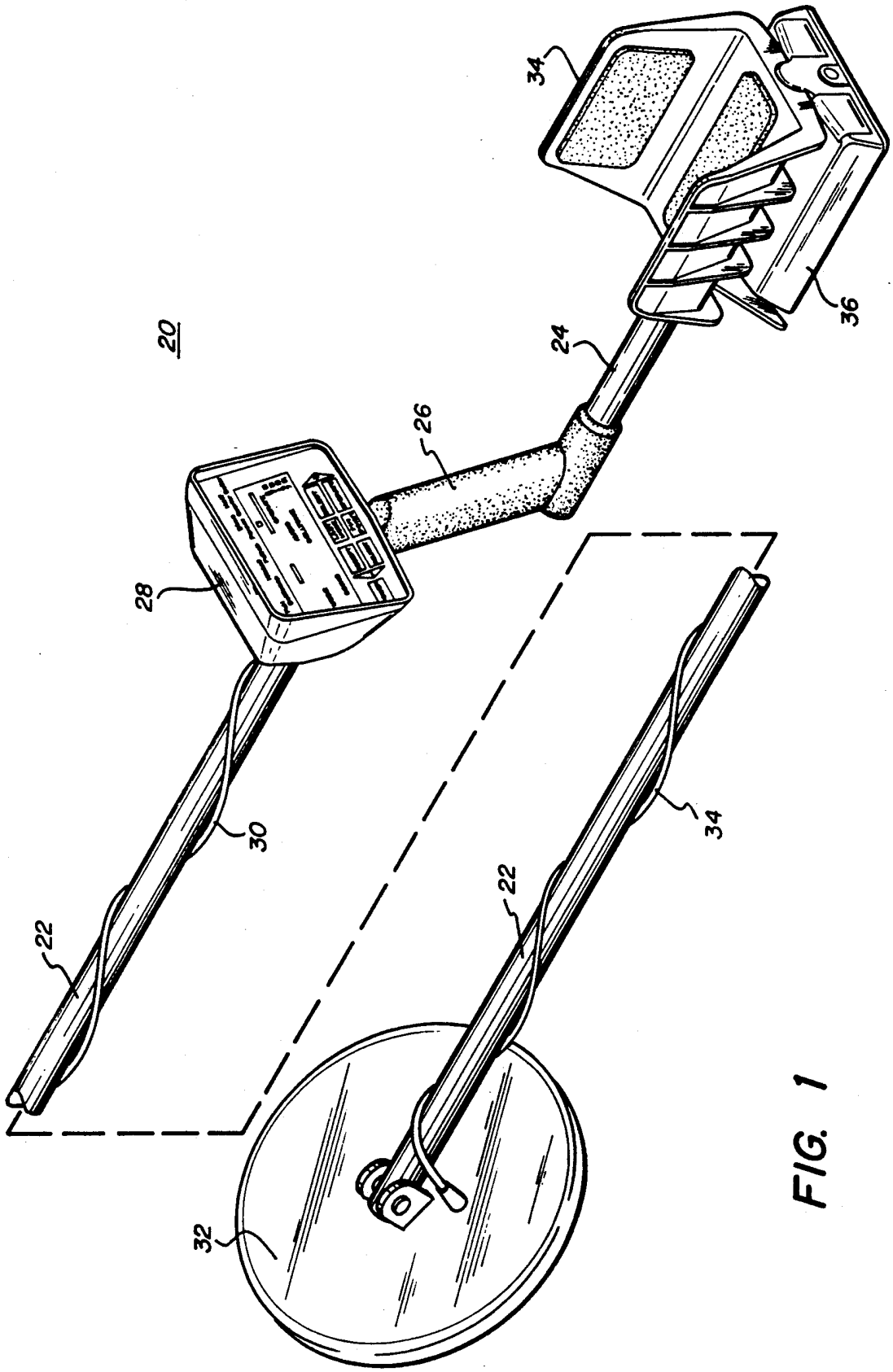



FIG. 1

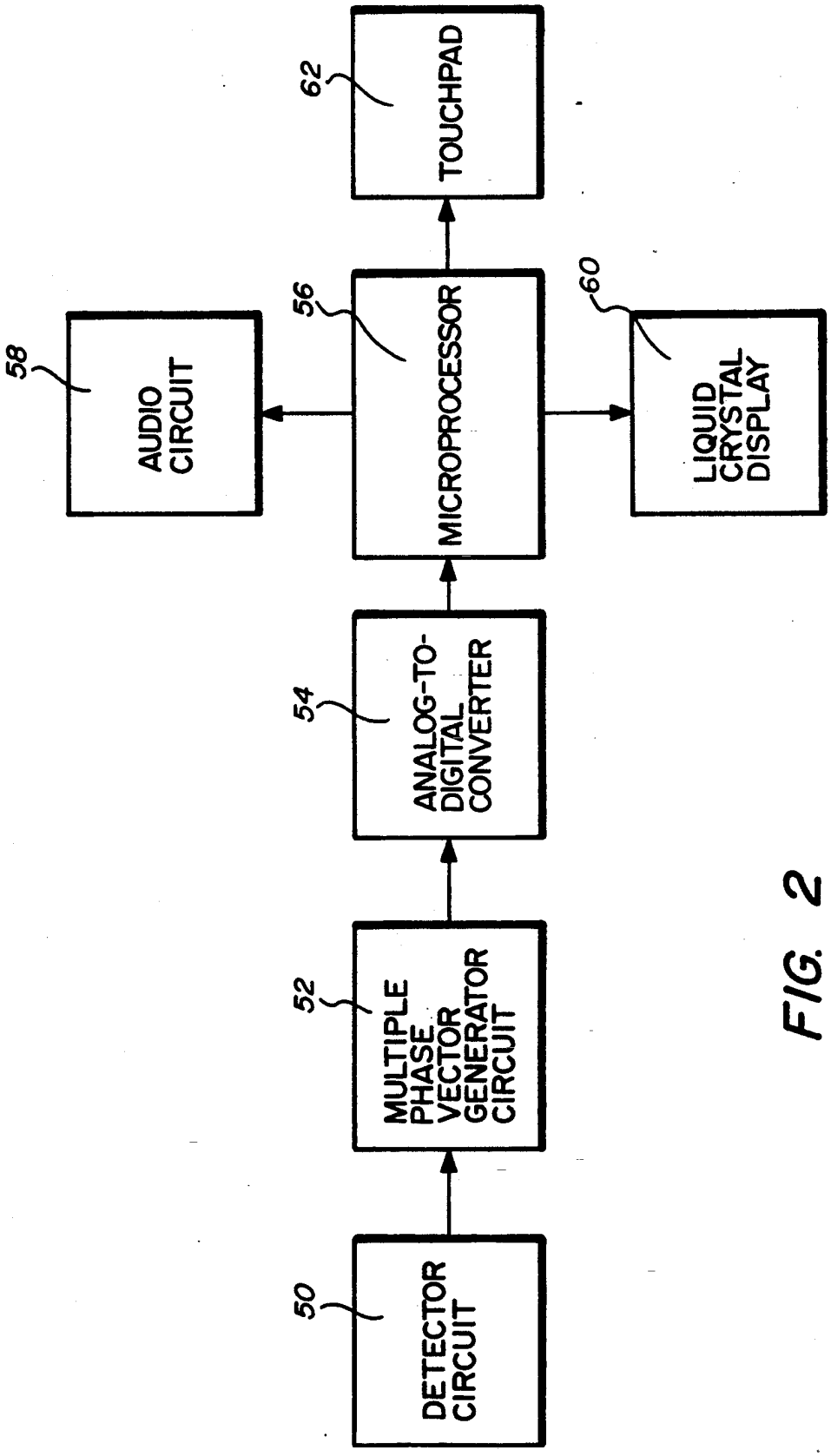

50
DETECTOR CIRCUIT
52
MULTIPLE PHASE VECTOR GENERATOR CIRCUIT
54
ANALOG-TO-DIGITAL CONVERTER
56
MICROPROCESSOR
58
AUDIO CIRCUIT
60
LIQUID CRYSTAL DISPLAY
62
TOUCHPAD

FIG. 2

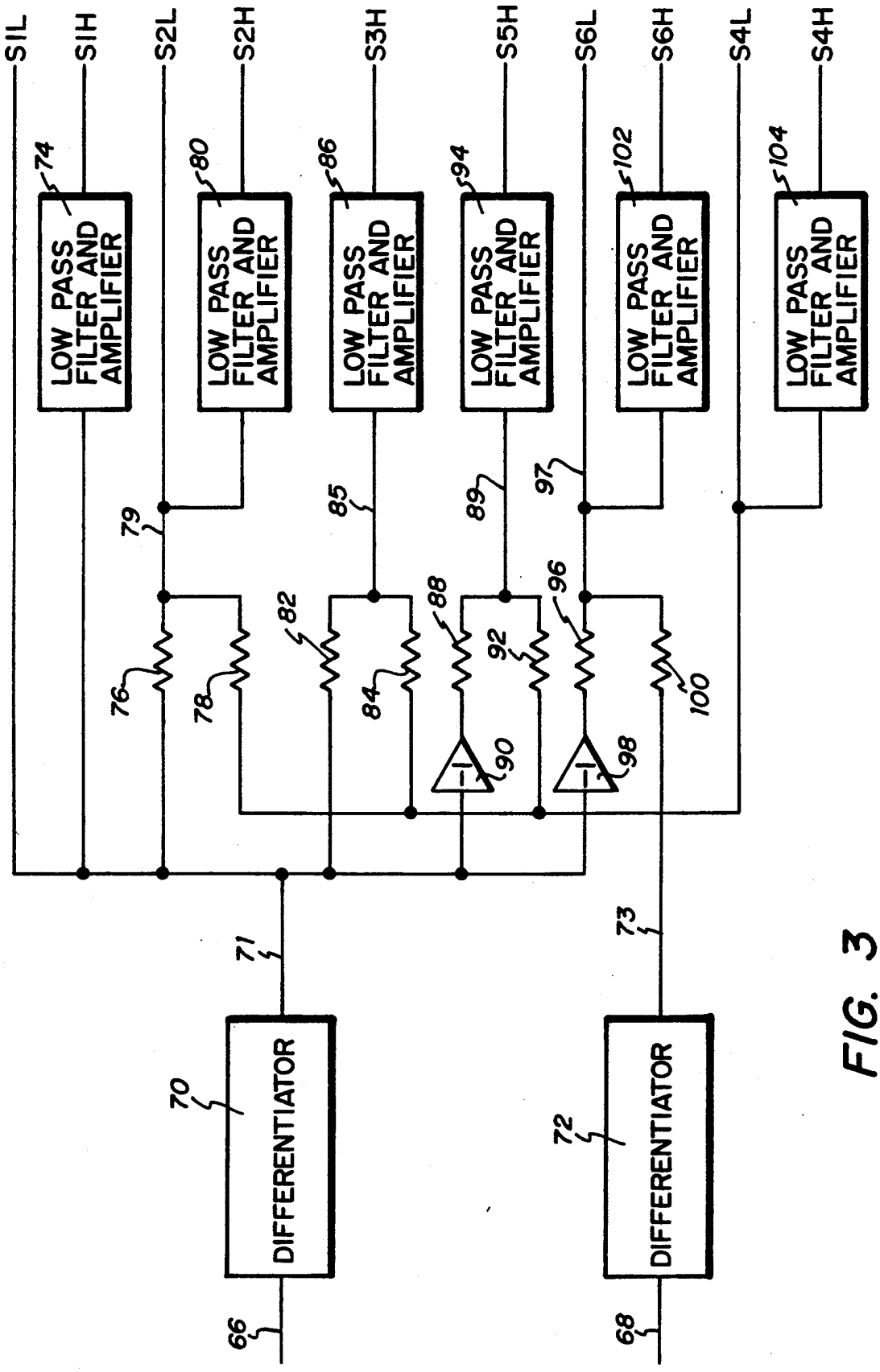

S1L
S1H
S2L
S2H
S3H
S5H
S6L
S6H
S4L
S4H
LOW PASS FILTER AND AMPLIFIER
74
80
86
94
102
104
79
85
89
97
76
78
82
84
88
92
96
100
90
98
71
73
DIFFERENTIATOR
70
72
66
68

FIG. 3

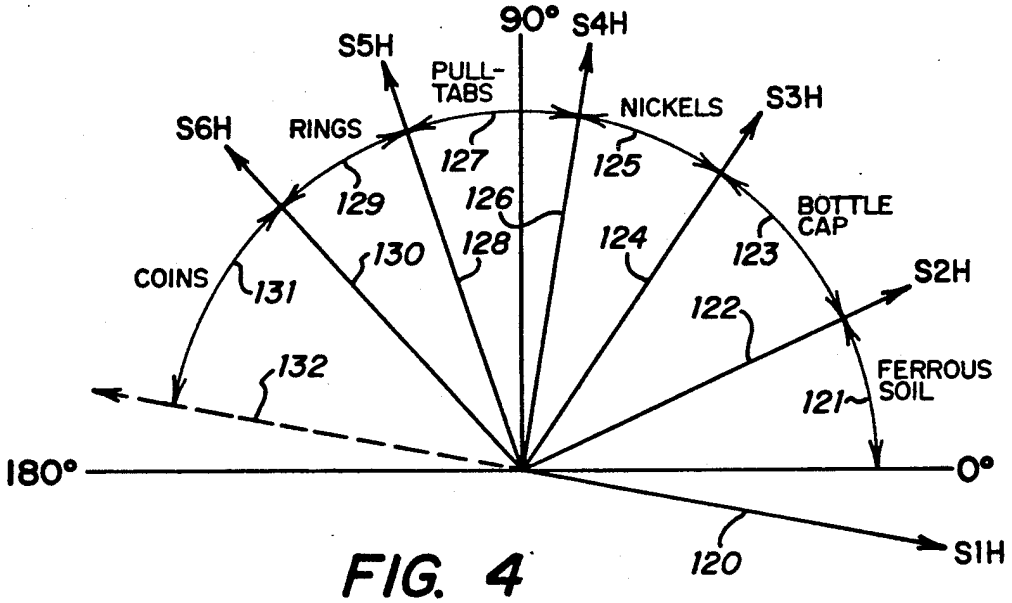

90°
S4H
S5H
PULL-TABS
NICKELS
S3H
S6H
RINGS
BOTTLE CAP
S2H
COINS
FERROUS SOIL
180°
0°
S1H
120
121
122
123
124
125
126
127
128
129
130
131
132

FIG. 4

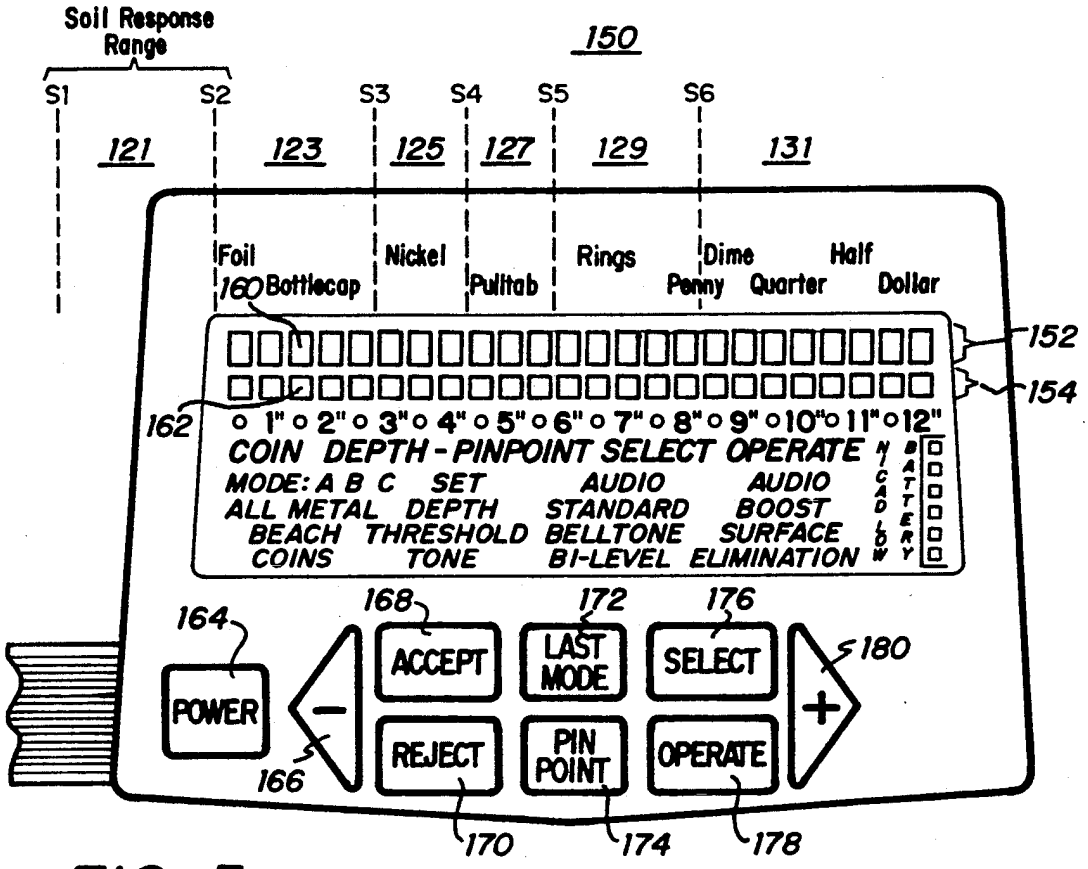

Soil Response Range
150
S1
S2
S3
S4
S5
S6
121
123
125
127
129
131
Foil
Bottlecap
Nickel
Pulltab
Rings
Dime
Penny
Half
Quarter
Dollar
160
152
154
162
1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12"
COIN DEPTH - PINPOINT SELECT OPERATE
MODE: A B C SET AUDIO AUDIO
ALL METAL DEPTH STANDARD BOOST
BEACH THRESHOLD BELLTONE SURFACE
COINS TONE BI-LEVEL ELIMINATION
MACDONALD BATTERY LOW
164
168
172
176
180
POWER
ACCEPT
LAST MODE
SELECT
REJECT
PIN POINT
OPERATE
166
170
174
178

FIG. 5

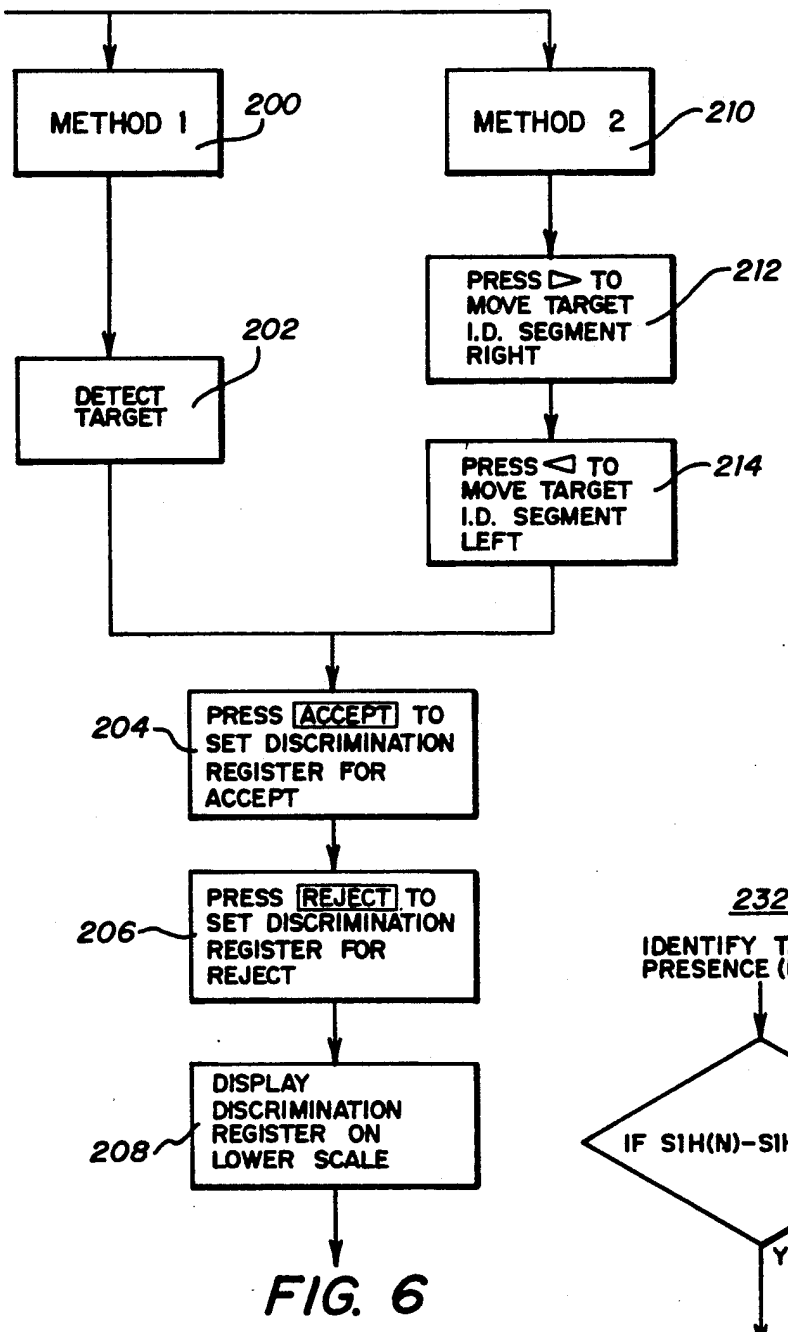

METHOD 1
200
METHOD 2
210
PRESS ▷ TO MOVE TARGET I.D. SEGMENT RIGHT
212
202
DETECT TARGET
PRESS ◁ TO MOVE TARGET I.D. SEGMENT LEFT
214
204
PRESS ACCEPT TO SET DISCRIMINATION REGISTER FOR ACCEPT
206
PRESS REJECT TO SET DISCRIMINATION REGISTER FOR REJECT
DISPLAY DISCRIMINATION REGISTER ON LOWER SCALE
208

FIG. 6

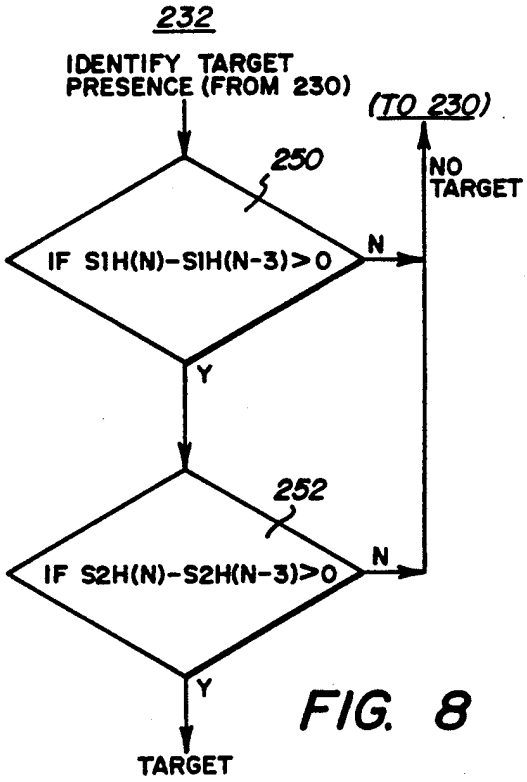
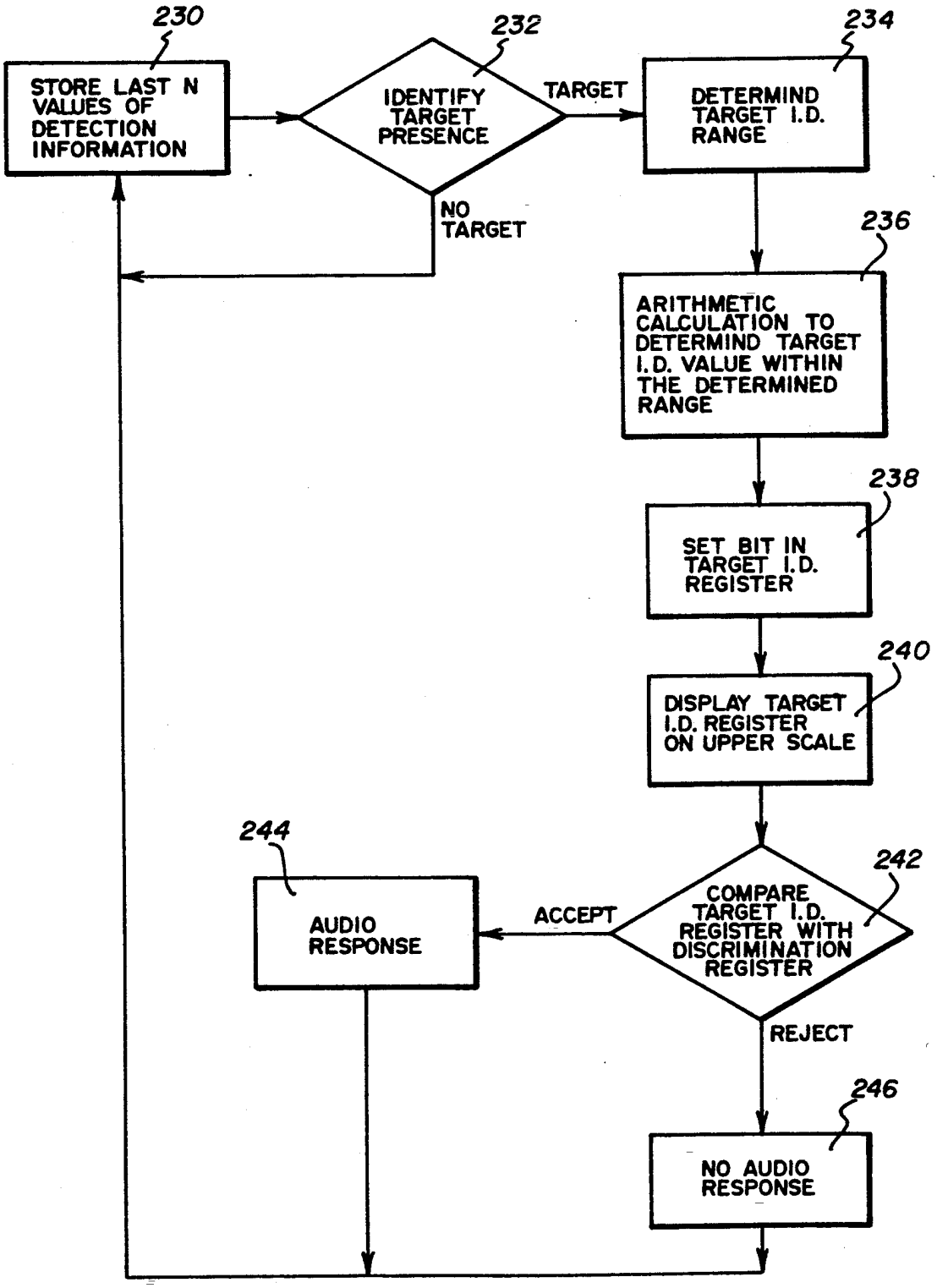

232
IDENTIFY TARGET PRESENCE (FROM 230)
(TO 230)
250
IF S1H(N)-S1H(N-3)>0
N
NO TARGET
Y
252
IF S2H(N)-S2H(N-3)>0
N
Y
TARGET

FIG. 8

FIG. 7


230
STORE LAST N VALUES OF DETECTION INFORMATION
232
IDENTIFY TARGET PRESENCE
TARGET
NO TARGET
234
DETERMIND TARGET I.D. RANGE
236
ARITHMETIC CALCULATION TO DETERMIND TARGET I.D. VALUE WITHIN THE DETERMINED RANGE
238
SET BIT IN TARGET I.D. REGISTER
240
DISPLAY TARGET I.D. REGISTER ON UPPER SCALE
242
COMPARE TARGET I.D. REGISTER WITH DISCRIMINATION REGISTER
ACCEPT
REJECT
244
AUDIO RESPONSE
246
NO AUDIO RESPONSE

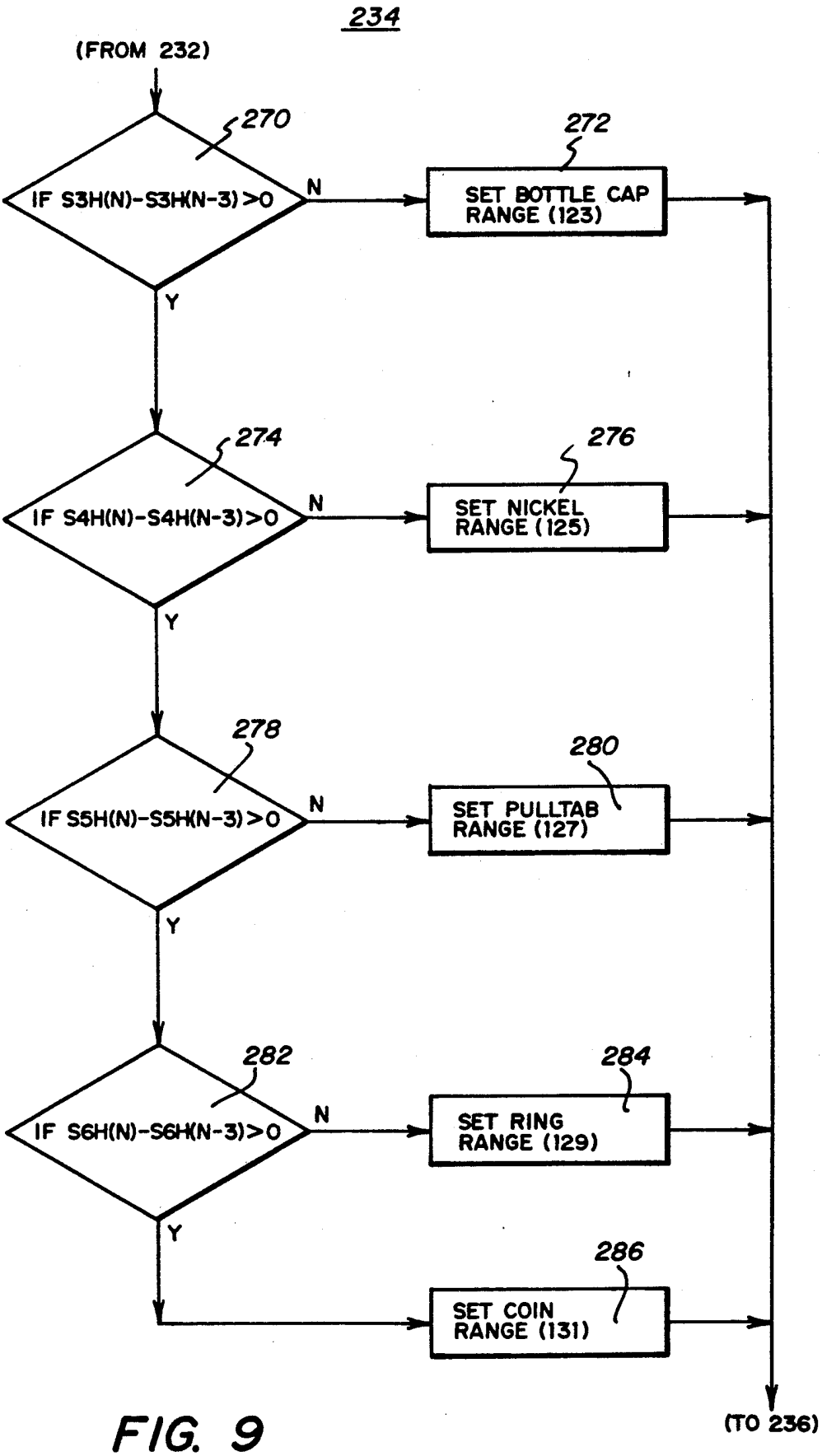

234
(FROM 232)
270
IF S3H(N)-S3H(N-3)>0
N
272
SET BOTTLE CAP RANGE (123)
Y
274
IF S4H(N)-S4H(N-3)>0
N
276
SET NICKEL RANGE (125)
Y
278
IF S5H(N)-S5H(N-3)>0
N
280
SET PULLTAB RANGE (127)
Y
282
IF S6H(N)-S6H(N-3)>0
N
284
SET RING RANGE (129)
Y
286
SET COIN RANGE (131)
(TO 236)

FIG. 9

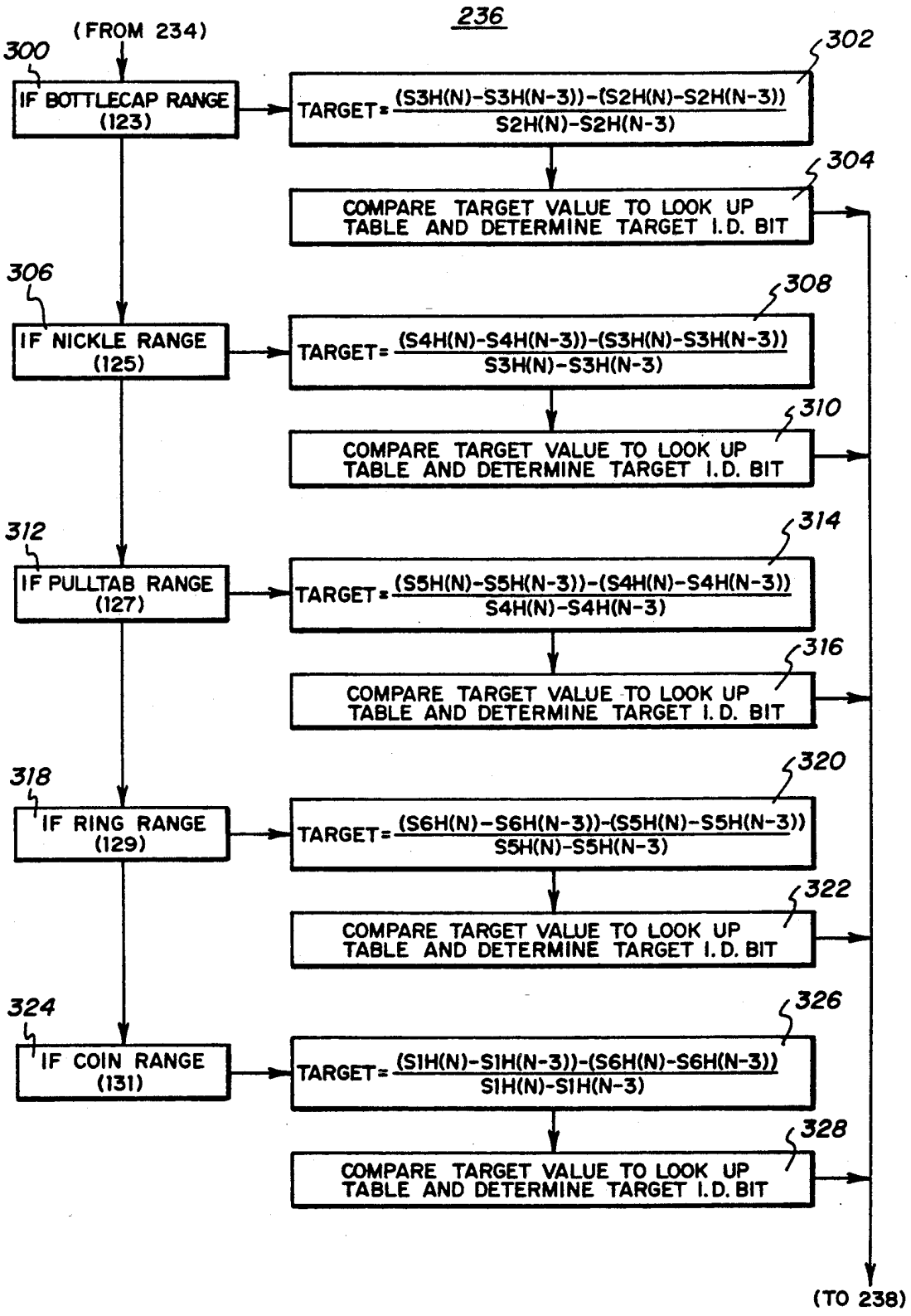

236
(FROM 234)
300
IF BOTTLECAP RANGE (123)
302
TARGET = (S3H(N)-S3H(N-3))-(S2H(N)-S2H(N-3)) / S2H(N)-S2H(N-3)
304
COMPARE TARGET VALUE TO LOOK UP TABLE AND DETERMINE TARGET I.D. BIT
306
IF NICKLE RANGE (125)
308
TARGET = (S4H(N)-S4H(N-3))-(S3H(N)-S3H(N-3)) / S3H(N)-S3H(N-3)
310
COMPARE TARGET VALUE TO LOOK UP TABLE AND DETERMINE TARGET I.D. BIT
312
IF PULLTAB RANGE (127)
314
TARGET = (S5H(N)-S5H(N-3))-(S4H(N)-S4H(N-3)) / S4H(N)-S4H(N-3)
316
COMPARE TARGET VALUE TO LOOK UP TABLE AND DETERMINE TARGET I.D. BIT
318
IF RING RANGE (129)
320
TARGET = (S6H(N)-S6H(N-3))-(S5H(N)-S5H(N-3)) / S5H(N)-S5H(N-3)
322
COMPARE TARGET VALUE TO LOOK UP TABLE AND DETERMINE TARGET I.D. BIT
324
IF COIN RANGE (131)
326
TARGET = (S1H(N)-S1H(N-3))-(S6H(N)-S6H(N-3)) / S1H(N)-S1H(N-3)
328
COMPARE TARGET VALUE TO LOOK UP TABLE AND DETERMINE TARGET I.D. BIT
(TO 238)

FIG. 10

# METAL DETECTOR HAVING TARGET CHARACTERIZATION AND SEARCH CLASSIFICATION

## FIELD OF THE INVENTION

The present invention pertains in general to metal detectors and in particular to a metal detector which can permit the operator to classify the search parameters for targets and characterize the targets which have been located.

## BACKGROUND OF THE INVENTION

It has been well established that metal detectors can identify targets to some degree based upon their physical composition due to the phase characteristics of a receive signal produced when the target object is in the field of an electromagnetic signal. Patents which illustrate target identification based upon phase include U.S. Pat. Nos. 4,334,191 to Podhrasky, 4,700,139 to Podhrasky and 4,507,612 to Payne.

Various metal detectors have been marketed which provide for target selection by operator classification. A representative product of this type is the Model "Eagle II" manufactured by White's Electronics of Sweethome, Oreg. In the operation of this metal detector, the operator can select target characteristics over a range of 1 to 100. This metal detector assigns a response number to targets based upon their electrical characteristics. The operator can program the detector to have selected search numbers which correspond to certain physical characteristics of desired targets. When the White's "Eagle II" detects an object and classifies it with the same number as has been previously selected by the operator, an audio output is produced along with a visual display indicating a match between the operator's programmed selection and the classification of a particular target. The display and operation, however, are principally numerical, with limited word indicators for target type, and the operator must relate particular numbers in the 1 to 100 range for correlation to desired targets.

In view of the desirability of easily classifying targets desired for detection and for indicating the nature of detected targets, there exist a need for a method of operation and a display for a metal detector which makes operation easy and simple for the operator for and provides accurate target classification and response.

## SUMMARY OF THE INVENTION

A selected embodiment of the present invention is a target characterization display for a metal detector in which there is produced a detection signal for objects that are present in the region of the detector. The display includes a first set of display segments and an array wherein each of the segments has a first and second display state. A discrimination memory is provided which has respective storage locations for each of the segments of the display. Each of the discrimination memory storage locations corresponds to a unique signal parameter range for targets of the metal detector. The value stored in each of the discrimination memory storage locations corresponds to the display state for the corresponding display segment. There is further included a second set of display segments arranged in an array wherein each of the segments has a first and second display state. The second set of display segments are positioned in proximity to the first set of display segments and there is a correspondence between the segments of the first and second sets. A target memory is provided which has respective storage locations therein for each of the display segments in the second set of segments. The values in the target memory storage locations are derived from the detection signal produced by the metal detector for the target object. The values stored in each of the target memory storage locations corresponds to the display state for the corresponding display segment.



In a further aspect of the present invention, there is provided a method of operation for a signal processing circuit used in conjunction with a metal detector circuit which produces multiple detection signals that represent a target vector signal related to target object composition. This method includes the steps of producing first and second vector signals which are related to the target composition. Next, there are produced a plurality of signals which are algebraic combinations of the first and second vector signals. Each of the vector signals is examined to determine a pair of the vector signals which encompass the phase range of the target vector signal. The pair of vector signals are algebraically combined to produce a target identification value. After production of the target identification value, a determination is made to find a subphase range into which the vector signals for the target is present. This indicates a physical characteristic for the target object.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a perspective view of a metal detector which incorporates the features of the present invention,

FIG. **2** is a block diagram of the electronic circuitry of the metal detector of the present invention,

FIG. **3** is a schematic circuit illustration of the multiple phase vector generator circuit shown in FIG. **2**,

FIG. **4** is a diagram illustration of the vector signals produced by the phase vector signals produced by the phase vector generator circuit shown in FIG. **3**,

FIG. **5** is an illustration of a liquid crystal display screen and a touchpad for the present invention,

FIG. **6** is a flow diagram illustrating the steps of initializing the operation of the metal detector of the present invention to set target discrimination,

FIG. **7** is a block diagram for the operational aspects of invention as applied to the microprocessor **56** for determining the target identification value, that is subphase range, for a target signal,

FIG. **8** is a detailed flow diagram representing the processes carried out in operational block **232** introduced in FIG. **7** for identifying the presence of a target,

FIG. **9** is a detailed flow diagram representing the operations carried out in block **234**, shown in FIG. **7**, for determining into which the target signal is classified, and

FIG. **10** is a detailed flow diagram illustrating the steps which are carried out in the operational block **23** of FIG. **7** for determining target identification values which in turn determines which segment of the target segments of the display are illuminated.

## DETAILED DESCRIPTION

The present invention is a circuit and display for a metal detector, such as a hobby-style metal detector **20** as shown in FIG. **1**. The detector **20** includes a first stem section **22**, second stem section **24** and an interconnecting hand grip **26**. A housing **28** includes electronic detection circuitry, described below, together with a display and an operator touchpad, also described below. The metal detector **20** is provided, with a search coil **32** which is connected via a cable **30** to the electronics within the housing **28**. The detector **20** is further provided with an arm rest **34** which is mounted on the stem section **24**. A battery and speaker housing **36** is connected to the stem **24** and arm rest **34**. A cable, not shown, extends from the housing **36** through the stem **24** and grip **26** to the housing **28** for connection to the electronic circuitry therein. Batteries within the housing **36** provide electrical power for the circuitry, described below. A speaker within the housing **36** provides an audio signal to the operator which is generated by the circuitry within the housing **28**.

The present invention is an easily usable metal detector which includes simple programming to select desired targets, a unique display to indicate the targets which have been programmed, as well as a display for classification of targets which have been found. The invention further includes a method of processing signals produced by a target object to provide target classification.

The operation of the electronics of the present invention is shown in a general block diagram in FIG. **2**. A detector circuit **50** functions in a conventional manner of a balanced induction metal detector to produce first and second phase detected signals. Such a circuit is described in U.S. Pat. No. 4,700,139, filed Oct. 29, 1984, to Podhrasky which is assigned to the assignee of the present application. U.S. Pat. No. 4,700,139, filed Oct. 29, 1984, is herein incorporated by reference.

The output from the detector circuit **50**, which corresponds to the signal lines **36** and **38** of U.S. Pat. No. 4,700,139 in FIG. **1** thereof, are input to a multiple phase vector generator circuit **52**. This circuit is described in detail in FIG. **3**. Circuit **52** produces multiple target vector signals which represent vector components of the detected target signal.

The target vector signals produced by the circuit **52** are provided to an analog-to-digital converter **54** which digitizes the received signals and provides them to a microprocessor **56**. A representative microprocessor which functions in accordance with the present invention is a Model MC68HC705 manufactured by Motorola.

The microprocessor **56** receives operator inputs from a touchpad **62**, which is further described, in reference to FIG. **5**. A liquid crystal display **60** is driven by the microprocessor **56**. This display is further shown in FIG. **5**. The microprocessor **56**, upon detection of a target signal having certain electrical characteristics and matching a previous discrimination selection, produces a signal that is transmitted to an audio circuit **58** to produce an audio output to an operator. Such an audio circuit is shown in U.S. Pat. No. 4,700,139.

Briefly, in operation, the metal detector **20** is operated such that the search coil is moved over the surface of the ground in the region of a target. The target distorts the electromagnetic field produced by the transmit coil and thereby induces a signal in the received coil. This received signal is phase demodulated to produce two phase detected signals which are provided by detector circuit **50** to the multiple phase vector generator circuit **52**. The circuit **52** utilizes these two phase detected signals to produce a plurality of vector signals representing phase components of the original target signal. These are produced by various summations and amplifications of the input signals The vector signals are then input to the analog-to-digital converter **54** for digitization and the resulting digital samples are provided to a microprocessor **56** for evaluation in accordance with selected processing steps which are further described below in detailed flow diagrams.

An operator determines the nature of a desired target and inputs this information through a touchpad **62** while observing the output from the liquid crystal display **60**. The microprocessor **56** stores the selection information and displays it to the operator through the liquid crystal display **60**. The operator initiates the searching procedure by inputting a command through the touchpad **62**. When the microprocessor determines that a target signal has been produced which has the characteristics previously selected by the operator, this will be indicated both on the liquid crystal display, **60** and by means of an audio tone which is generated through the audio circuit **58**. A further detailed description of the metal detector in accordance with the present invention is provided in reference to the descriptions of the following Figures.

The multiple phase vector generator circuit **52**, introduced in FIG. **2**, is described in detail in FIG. **3**. Signals at lines **66** and **68** are first and second phase detected signals which are produced as described in reference to U.S. Pat. No. 4,700,139 at lines **36** and **38** shown in FIG. **1** thereof. The phase detected signal at line **66** is provided to a differentiation circuit **70** which produces a second derivative of the input signal and provides this second derivative signal at an output line **71**. The phase detected signal at line **68** is provided to a differentiation circuit **72** which likewise provides a second derivative signal at an output line **73**. The signal at line **71** is designated as S1L which stands for signal **1**, low amplitude. The signal at line **71** is input to a low pass filter and amplifier **74** which produces a signal termed S1H which is a low pass filtered and amplified signal derived from the signal S1L.

The signal at line **73** is designated as S4L. The S1L signal is transmitted through a resistor **76** and the S4L signal is transmitted through a resistor **78** to a line **79** to produce a signal S2L. The S2L signal is transmitted through a low pass filter and amplifier **80** to produce a signal S2H.

The S1L and S4L signals are likewise transmitted through respective resistors **82** and **84** to a line **85** to produce a summation signal which is transmitted through a low pass filter and amplifier **86** which produces a signal S3H.

The S1L signal at line **71** is transmitted through an inverter **90** and a resistor **88** to a line **89**. The S4L signal is provided through and a resistor **92** to the line **89** for summation with the S1L signal. The resulting summation signal at line **89** is transmitted through a low pass filter and amplifier **94** to produce a signal S5H.

The S1L signal at line **71** is also transmitted through an inverter **98** and a resistor **96** to a line **97**. The S4L signal at line **73** is transmitted through a resistor **100** for combination with the S1L signal at line **97** to produce a signal S6L. The S6L signal at line **97** is provided to a

low pass filter and amplifier **102** for production of a signal S6H.

As described above, the "H" signals are amplified and filtered versions of the corresponding "L" signals. The signals S1L, S1H, S2L, S2H, S3H, S4L, S4H, S5H, S6L and S6H are target vector signals which represent selected phase components for target signals Without the "H" and "L" designations, the signals are S1, S2, S3, S4, S5 and S6.

Further referring to FIG. **4**, there is illustrated a phase diagram which represents target vector signals produced by the circuit **52** and a definition of targets which would correspond to the vector signals. The signals S1H, S2H, S3H, S4H, S5H and S6H correspond respectively to vectors **120**, **122**, **124**, **126**, **128** and **130**. The vectors define ranges as shown in the vector diagram. The vectors **120** and **122** define a range **121** which essentially includes the responses of soil with nonconductive iron content as well as soil with moderate conductive components. The vectors **122** and **124** define a vector range **123** which defines a range of responses which include targets such as bottle caps. The vectors **124** and **126** define a range **125** which includes targets such as nickels. The vectors **126** and **128** define a range **127** which includes targets such as pull-tabs. The vectors **128** and **130** define a vector range **129** which includes targets such as rings. Finally, the vector **130** and line **132** define a phase range **131** which includes targets such as highly conductive coins. These phase ranges are related to display segments which are shown in FIG. **5**.

Referring to FIG. **3**, the resistor values are as follows:

Resistor **76**=22K ohms
Resistor **78**=270K ohms
Resistor **82**=22K ohms
Resistor **84**=4.9K ohms
Resistor **88**=68K ohms
Resistor **92**=47K ohms
Resistor **96**=47K ohms
Resistor **100**=47K ohms

A further significant aspect of the present invention is a display **150** which is illustrated in FIG. **5**. The display includes a linear array **152** of target indication segments, one of which is segment **160** It further includes a linear array **154** of discrimination segments, one of which is segment **162**. The segments in arrays **152** and **154** are preferably liquid crystal display segments which have first and second display states, namely light and dark corresponding to reflective and nonreflective states.

The signals **S1**, **S2**, **S3**, **S4**, **S5** and **S6** are marked on FIG. **5** together with the ranges **121**, **123**, **125**, and **127**, **129** and **131**. These target vector signals and ranges correspond to sections of the display for the arrays **152** and **154**. The target array **152** segments are illuminated by the microprocessor **56** when a target signal is classified in one of the categories corresponding to one of the twenty-four segments.

The array **154** segments are selected by an operator to define particular targets for which the operator wishes to either receive an audible notification when they are detected or wishes to specifically reject.

The metal detector **20** has various modes of operations which are indicated on the display **150** by the operational indicators "COIN DEPTH", "PINPOINT SELECT" and "OPERATE".

The display **150** further includes various operational modes and programming features which are indicated by words.

The operator provides inputs to the microprocessor **56** by operation of a touchpad **62**. The touchpad **62** includes a power key **164**, a negative increment key **166**, an accept key **168**, a reject key **170**, a last mode key **172**, a pinpoint key **174**, a select key **176**, an operate key **178** and a positive increment key **180**. Operation of the subject metal detector in conjunction with the display **150** is further described below.

Referring now to FIG. **6**, there is illustrated a flow diagram for discrimination selection setup of the metal detector **20** in accordance with the present invention. Target discrimination can be implemented for either accepting specifically defined targets or rejecting specifically defined targets. This further can be done by either first or second methods as described herein. Basically, the operator can (1) accept or reject a specifically defined signal target type or (2) physically detect the target through operation of the metal detector **20** and following classification of the target select whether that type of target is to be accepted or rejected.

Further referring to FIG. **6**, entry is made to an operational block **200** for implementing method one or an operational block **210** for implementing method two. In method one, operation is transferred to an operational block **202** in which the operator utilizes the metal detector **20** in the operate mode to actually detect a target object. When this is done, the microprocessor **56** displays an activated segment within the segments of array **152** to indicate the classification of the target. This could be, for example, segment **160**. This would indicate detection of an object such as foil or a bottle cap. Continuing to an operational block **204**, the operator can then depress either the +key **180** to set a discrimination register, a register corresponding to the display segment **154**, to accept the target or can enter operational block **206** and depress the−key **166** to set the discrimination register for rejecting that particular type of target. Continuing to an operational block **208**, the appropriate ones of the discriminator segments **154** are illuminated to indicate that the discrimination register has been set to either accept or reject targets that have a corresponding classification. Following the completion of method one, the operation transfers from block **208** to an exit to await a further operator selection. This discrimination register is either a register in the microprocessor **56** or a logical register in the microprocessor software.

Further referring to FIG. **6**, if method two is selected for discrimination programming, entry is made to the operational block **210** and further to an operational block **212**. Within the block **212**, the positive increment key **180** is depressed to move an illuminated segment of the array **154** to the right as indicated by the corresponding arrow for the key **180**. For each illuminated segment of array **154**, such as segment **162**, the operator can determine whether to accept or reject that particular type of target. Continuing to an operational block **214**, the operator has the option of moving the key **166** to the left for making target discrimination selection. Following the operational block **214**, the procedure continues through the previously described operational blocks **204**, **206** and **208** for the operator to press either of keys **168** or **170** to set the discrimination register to either accept or reject the determined type of target. Further, after such a selection is made, the discrimination segments of array **154** are appropriately set and illuminated.

Thus, in FIG. **6**, the metal detector **20** is set up by the operator to selectively accept or reject target signals

which have been classified, as further described below. The display **150** indicates in array **154** which segments (target types) have been selected. This is discrimination selection.

The functional operation of the microprocessor **56** for evaluating signals provided by the circuit **52** and producing the segment illumination for segments of array **152** and array **154**, as well as for the control signal for the audio circuit **58** is shown in the flow diagram illustrated in FIG. **7**. Operation is begun with an operational block **230** in which the detector **20** receives the digital signals from the analog-to-digital converter **54** and stores the last N values of detection information. For the present embodiment, this comprises the last four samples of each of the ten vector signals which have been received for the target signal. The group of ten signals are sampled every five milliseconds. Thus, the processing is carried out after the target signals have been collected. However, this is done in a very fast processing technique such that the response to the operator occurs within a very short human response time.

Continuing to a decision block **232**, an inquiry is made to determine if a target is present within the received signal. This operation is described in more detail in reference to FIG. **8**. If no target is detected, the exit is taken from the block **232** to return control to the block **230**. Thus, the microprocessor metal detector **20** cycles between the blocks **230** and **232** receiving and processing the information to detect the existence of a target when in the operating mode. If a target is detected, as determined by the decision block **232**, exit is taken through the target exit to an operational block **234**.

Within the operational block **234**, a determination is made for the target ID range for the received target signal. This is a classification of the target signal to be within one of the ranges **121**, **123**, **125**, **127**, **129** and **131** as described above and shown in FIGS. **4** and **5**. A detailed flow diagram illustrating this operation and the method of determining the particular target ID range is shown in FIG. **9**.

After the target ID range has been determined, control is transferred to an operational block **236** in which arithmetic calculations are carried out to determine the target ID value within the previously determined range. This is done using the two vectors which define the selected range. The operations carried out in operational block **236** are described in detail in reference to a detailed flow diagram in FIG. **10**. The result of the processing carried out in operational block **236** is an identification of a target ID value which is a value that corresponds to one of the twenty-four segments within the target segments of array **152**. Note that each of the ranges is subdivided into categories which are termed "target ID values". Each of these values corresponds to a segment of the display array **152** and also to a segment of the display array **154**.

After the target signal has been classified down to the level of a target ID value, control is transferred to an operational block **238** in which the microprocessor **56** sets a bit in a target ID register which corresponds to one of the segments of array **152**. Each of the segments within the segments of array **152** corresponds to a particular target ID value. A target ID register is provided which has a memory storage location for each of the segments of array **152**. Each of the memory locations corresponds to a range of target ID values, that is, a particular narrow range of phase characteristics for the target signal. When the target has been identified to have a particular target ID value, the microprocessor **56** sets a display bit in the corresponding location of the target ID register to cause the corresponding one of the segments in target array **152** to be illuminated. After this is done, operation is carried out in block **240** to display the target ID register on the upper scale of display **150**. The upper scale comprises the segments of target array **152**. Thus, the one of these segments, which corresponds to the physical characteristics of the target, is illuminated.

The target ID register can be either a register in the microprocessor **56** as a logical register handled by the software in operation by the microprocessor.

Following the operational block **240**, entry is made to a decision block **242** in which the contents of the target ID register are compared with the contents of the discrimination register. The discrimination register functions to activate the segments of discrimination array **154**. The discrimination register has a memory storage location corresponding to each of the segments of array **154**. Note, as described above, each of the segments within the segments of array **154** corresponds to a particular physical characteristic of a target and likewise the segments in array **154** correspond on a one-to-one basis to the segments of array **152**. Thus, within operational block **242** a comparison is made to determine which of the corresponding memory locations have similar values (bits) to indicate that a target has been found with a particular target ID value and the operator has previously set a similar discrimination value into the discrimination register. If there is a comparison, the accept exit is taken to an audio response block **244** in which the microprocessor **56** generates a control signal to the audio circuit **58** to produce an audio signal to the operator to indicate that a desired target object has been detected.

If the decision block **242** determines that there are no comparisons between the target ID register and the discrimination register, therefore no target object has been found which corresponds to what was set in the discrimination register, the reject exit is taken to an operational block **246** and the microprocessor **56** does not send any type of audio control signal to the audio circuit **58**. However, note that the target segments of array **152** are illuminated showing the type of target found so that the operator visually knows that a target has been found and that it has a particular physical characteristic. The outputs from the blocks **244** and **246** transfer control of the microprocessor **56** back to the operational block **232** to again store received values and monitor for the detection of a target. Further details of the operations described in reference to FIG. **7** are presented in FIGS. **8**, **9** and **10**.

Referring now to FIG. **8**, there is shown a more detailed explanation of the operation which occurs within operational block **232** in FIG. **7**. The function of this block is to identify the presence of a target signal within the received signal. This is done by examining the slope of the vector signals **S1** and **S2**. In a decision block **250**, an inquiry is made to determine if the difference between the signal component **S1H(N)** and **S1H(N-3)** is greater than zero. This indicates that the **S1** signal has a positive slope. If this difference is not greater than zero, the no exit is taken and return is made to the operational block **230** to again receive values for the received signal. If the answer to the inquiry in operational block **250** is positive, the yes exit is taken to a decision block **252** in which an inquiry is made to deter-

mine if S2H(N)−S2H(N-3) is greater than zero This inquiry determines if the slope is positive for the S2 signal. If the response to this inquiry is negative, the no exit is taken and return is made to the operational block **230**. But, if the response to the inquiry is positive, the yes exit is taken and entry is made to the operational block **234** for processing of the target signal. The operations described in reference to FIG. **8** determine that there are positive slopes for the signals S1 and S2 at a particular time thereby indicating that a valid, non-ground, target signal is present for processing.

Referring to FIG. **9**, there is illustrated a detail flow diagram representing the operations carried out in operational block **234** shown in FIG. **7**. The function of the block **234** is to determine the range within which the target signal is present. The possible ranges are **121**, **123**, **125**, **127**, **129** or **131** as described in reference to FIGS. **3** and **4**. Referring now to FIG. **9**, from operational block **232**, entry is made to a decision block **270** to determine if the difference between the S3 signal at two sample times is positive or negative. This is a determination of slope between the sample points N and N-3. If the response is negative, the no exit is taken and entry is made to an operational **272** in which the bottle cap range, range **123**, is selected. Following block **272**, return is made to the operational block **236** for the arithmetic determination of the target ID value, which corresponds to one of the segments **152**.

If the determination in decision block **270** is positive, the yes exit is taken to a decision block **274**. Within block **274**, the determination S4H(N)−S4H(N-3) greater than zero is made. This likewise is a comparison of the amplitude of the signal S4H at two different times separated by three samples The approximate sample rate for the analog-to-digital converter **54** for use in the present invention is at five millisecond intervals. If the response in decision block **274** is negative, the no exit is taken and entry is made to operational block **276** in which the nickel range, which is range **125**, is set. Control is then transferred from operational block **276** to the block **236**.

If the response to the inquiry in operational block **274** is positive, that is the slope of the S4 signal is positive, the yes exit is taken to a decision block **278** in which the inquiry is made for S5H(N)−S5H(N-3) greater than zero. If this inquiry is negative, the no exit is taken and entry is made to an operational block **280** in which range **127** is set for the type of targets corresponding to pull-tabs. Following block **280**, return is made to operational block **236**.

If the response to decision block **278** is positive, then the yes exit is taken to a decision block **282** in which the inquiry is made for S6H(N)−S6H(N-3) greater than zero. If this inquiry is negative, the no exit is taken to an operational block **284** in which range **129** is set. This corresponds to objects such as rings.

Following operational block **284**, return is made to operational block **236** for further signal evaluation.

If the response in decision block **282** is positive, the yes exit is taken to an operational block **286** in which range **131** is set. This range corresponds to objects such as coins. Following block **286**, control is transferred to operational block **236**.

In summary, the operations carried out in this reference to FIG. **9** comprise determining which of the ranges the target signal is in as shown in FIG. **4**.

Referring now to FIG. **10**, there is shown in detail the operations which are specified for operational block **236** shown in FIG. **7**. The overall function of block **236** is to determine a particular target ID value within a determined range for the target signal. As described above, the range is determined in operational block **234**. The functions carried out in operational block **236** comprise determining a subphase range for the target signal within the determined range. Each of the subphase ranges corresponds to one of the display segments **160** of target array display **152**. There are no display segments for range **121**, which is a soil response. Range **123** has five segments, each of which corresponds to a particular subphase range of the range **123**. Range **125** has three segments and corresponding three subphase ranges. Range **127** has three segments, range **129** has five segments and range **131** has eight segments.

Operational block **234** determines the range in which a target signal is present and operational block **236** determines which of the subphase ranges the target signal is present for selecting one of the segments **152**.

Further referring to FIG. **10**, entry is made to a first operational block **300** for determining if the bottle cap range has been previously determined. If so, the yes exit is taken to an operational block **302** in which signal processing is performed using the S2 and S3 signals at offset time points. This mathematical function is shown in operational block **302**. The result of this processing is a target value, a number. Following operational block **302**, control is transferred to an operational block **304** in which the target value is applied to a look-up table to determine the corresponding target ID bit, that is the subphase range within the range **123**. As noted above, there are four subphase ranges. Therefore, all the possible target values have to fall into one of these four possible sub-ranges.

If the response at the block **300** is negative, the no exit is taken to an operational block **306** to determine if the range **125** has been previously determined in block **234**. If so, exit is made to an operational block **308** to carry out a target value computation as shown within this block. This produces a number for a target value. The range for block **308** is **125** which has three segments of the array **152**. This number is then used in the next sequential operational block **310** where it is applied to a look-up table for determination of a target ID bit. There are three possible bits which can be selected, which correspond to the segments **152** for the range **125**. The result of the operation in block **310** is identification of one of these three bits. Following block **310** control is returned to operational block **238**.

If the response in block **306** is negative, control is transferred to an operational block **312** in which it is determined if the range **127** for pull-tabs has been previously selected. If so, control is transferred to an operational block **314** in which an algebraic operation is carried out with the S4 and S5 signals to produce a number for a target value. Following operational **314**, control is transferred to an operational block **316** in which the target value is applied to a look-up table to determine the corresponding target ID bit. There are three possible bit locations for range **127** as corresponding to the segments **152** illustrated in FIG. **5**. Upon selection of one of these three bits, control is transferred from operational block **316** to the operational block **238**.

If the operational block **312** has a negative response, the no exit is taken to an operational block **318** in which determination is made if the range **129** has been selected in block **234**. If so, control is transferred to an operational block **320** in which an algebraic operation is con-

ducted to determine a target value utilizing the signals S5 and S6 which existed at times N and N-3. Following calculation of the target value in block **320**, control is transferred to an operational block **322** in which the determined target value is applied to a look-up table for selecting a target ID bit, corresponding to one of the possible five segments **152** in the display **150**. Once a selection is made for this target ID bit, control is transferred to operational block **238**.

If the block **318** determines that the range **129** has not been selected, control is transferred to an operational block **324** to determine if the coin range **131** has been selected. If so, control is transferred to an operational block **326** in which an algebraic operation is conducted to determine the target value based upon the signals S1 and S6. Following the operational block **326**, this numeric target value is applied in operational block **328** to a look-up table for determining the target ID bit. There are eight bits possible for range **131**, each of these bits corresponding to the segments of array **152** within the range **131**. Following the selection of the target ID bit in operational block **328**, control is then transferred to the operational block **238**.

All of the sub-ranges are essentially uniformly distributed across the individual ranges.

In summary, the present invention is a metal detector in which there is provided a display and touchpad such that the operator can select to either accept or reject particular target signals associated with certain types of targets. This is the operator's discrimination function and the results of the selection is displayed in a linear array of segments, each of which may have a reflective or nonreflective state. In operation, the circuitry of the metal detector processes the received signal to produce multiple target vector signals These signals define a plurality of phase ranges and the target signal is classified within one of these ranges. Further algebraic operations upon the pair of signals which define the phase range are carried out to select a discrete subphase range that more precisely defines a characteristic of the signal, which corresponds to a physical characteristic of the target object This is determined by producing a target ID value. Once this value is determined, a segment of the display **152** is illuminated to indicate the nature of the object which has been detected. If the illuminated segment corresponds to a previously selected segment in the discrimination, array **154**, there is produced an audio output to the operator indicating that the target selected by discrimination had been found.

Although one embodiment of the invention has been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutes of parts and elements without departing from the scope of the invention.

What is claimed is:

**1**. A target characterization display for a metal detector which produces a detection signal for objects in a region of the detector, comprising:

a first set of arrayed display segments each having first and second display states,

a discrimination memory having respective storage locations therein corresponding to each of said display segments in said first set, each discrimination memory storage location corresponding to a unique signal parameter for metal detector targets and wherein the value stored in each of said discrimination memory storage locations controls the display state for the corresponding display segment,

a second set of arrayed display segments each having first and second display states, said second set of display segments positioned proximate said first set of display segments and having a correspondence between the segments of said first set and said second set, and

a target memory having respective storage locations therein for each of said display segments in said second set, wherein the values in said target memory storage locations are derived from phase detected signals and wherein the value in each of said target memory storage locations controls the display state for the corresponding display segment.

**2**. A target characterization display for a metal detector as recited in claim, further including:

means for detecting when corresponding ones of said storage locations in said discrimination and target memories have been set to values for driving the corresponding display segments to an active display state, and for generating a control signal upon said detecting, and

an audio output circuit connected to receive said control signal and for producing an audio output upon receipt of said control signal.

**3**. A target characterization display for a metal detector which produces a detection signal for objects in a region of the detector, comprising:

a first set of linearly arrayed display segments each having first and second display states,

a discrimination memory having respective storage locations therein corresponding to each of said display segments in said first set, each discrimination memory storage location corresponding to a unique signal parameter for metal detector targets and wherein the value stored in each of said discrimination memory storage locations controls the display state for the corresponding display segment,

a second set of linearly arrayed display segments each having first and second display states, said second set of display segments positioned essentially in parallel with said first set of display segments and having a one-to-one correspondence between the segments of said first set and said second set, and

a target memory having respective storage locations therein for each of said display segments in said second set, wherein the values in said target memory storage locations are derived from phase detected signals and wherein the value in each of said target memory storage locations controls the display state for the corresponding display segment.

**4**. A target characterization display for a metal detector as recited in claim **3**, further including:

means for detecting when corresponding ones of said storage locations in said discrimination and target memories have been set to values for driving the corresponding display segments to an active display state, and for generating a control signal upon said detecting, and

an audio output circuit connected to receive said control signal and for producing an audio output upon receipt of said control signal.

**5**. A target characterization display for a metal detector which has transmit and receive coils for producing

a detection signal and phase detection circuits for producing phase detected target signals from said detection signal, comprising:

a first set of linearly arrayed display segments, each having first and second display states,

a discrimination memory having respective storage locations therein corresponding to each of said display segments in said first set, each discrimination memory storage location corresponding to a unique signal parameter for metal detector targets and wherein the value stored in each of said discrimination memory storage locations controls the display state for the corresponding display segment,

a second set of linearly arrayed display segments each having first and second display states, said second set of display segments positioned essentially in parallel with said first set of display segments and having a one-to-one correspondence between the segments of said first set and said second set, and

a target memory having respective storage locations therein for each of said display segments in said second set, wherein the values in said target memory storage locations are derived from said phase detected signals and wherein the value in each of said target memory storage locations controls the display state for the corresponding display segment.

6. A target characterization display for a metal detector as recited in claim 5, further including:

means for detecting when corresponding ones of said storage locations in said discrimination and target memories have been set to values for driving the corresponding display segments to an active display state, and for generating a control signal upon said detecting, and

an audio output circuit connected to receive said control signal and for producing an audio output upon receipt of said control signal.

7. A method of operation for a signal processing circuit used in conjunction with a metal detector circuit which produces multiple detection signals that represent a target vector signal related to target object composition, the method comprising the steps of:

producing first and second vector signals which are related to target composition,

producing a plurality of vector signals which are algebraic combinations of said first and second vector signals,

examining each of said vector signals to determine a pair of said vector signals which encompasses the target vector signal,

algebraically combining the pair of vector signals to produce a target identification value, and

determining within which one of a plurality of predefined subphase ranges, which are between said pair of vector signals, said target identification value is present, thereby indicating a characteristic of the target object.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION



PATENT NO. : 5,148,151

DATED : September 15, 1992

INVENTOR(S) : Podhrasky

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 1, line 19, immediately following the word "phase", please insert -- characteristics --.

Col. 1, line 45, please delete the word "exist" and substitute therefor the word -- exists --.

Col. 1, line 47, please delete the second occurrence of the word "for".

Col. 2, line 45, immediately following the words "FIG. 4 is a", please insert --phase--.

Col. 2, line 54, immediately following the word "of", please insert -- the present --.

Col. 2, line 62, immediately following the word "determining", please insert -- a range --.

Col. 2, line 65, please delete the numeral "23" and substitute therefor -- 236 --.

Col. 3, line 10, please delete the punctuation mark ",".

Col. 3, line 55, please delete the second occurrence of the punctuation mark ",".

Col. 4, line 24, please delete the punctuation mark ",".

Col. 8, Line 23, immediately following the word "target", please insert -- , --.

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION



PATENT NO. : 5,148,151

DATED : September 15, 1992

INVENTOR(S) : Podhrasky

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 11, Line 47, immediately following the word "discrimination", please delete the punctuation mark -- , --.

Col. 12, Line 19, immediately following the word "claim", please insert -- 1 --.

Col. 14, Line 26, immediately following the word "between", please insert -- the vector signals of --.

Signed and Sealed this

Twenty-eighth Day of December, 1993

*Attest:*

BRUCE LEHMAN

*Attesting Officer*

*Commissioner of Patents and Trademarks*