Metal detector with display.

A metal detector having a receive signal responsive to detected metal objects and having a display panel (139) that can simultaneously display a plurality of phase angles (205) on one scale associated with the receive signal. Additionally, the display panel can simultaneously display on the other scale (210) a second variable associated with the receive signal at each particular phase angle. The second variable is user selectable and can be either (1) a count of the number of times when the signal amplitude exceeds a predetermined threshold level at a particular phase angle or (2) the signal amplitude when the signal is at a particular phase angle.
Field of Invention

The present invention relates to the field of metal detectors, and more particularly to a means of graphically displaying signal information that reflects signal characteristics responsive to metal objects which pass beneath a search head of the metal detector.

Background of the Invention

As induction balanced metal detector, of the type used to locate coins, rings and other treasure buried in soil within a few feet of the surface, has a search head that houses a transmit coil and receive coil. The metal detector has circuitry that transmits a periodic signal to the transmit coil as the search head is manually swept over a ground surface to detect buried metal objects. When the transmit coil passes over a metal object, a signal is generated in the receive coil due to perturbations in the magnetic field which cause the AC inductive coupling between the transmit and receive coils to become unbalanced. These receive coil signals are responsive to target characteristics such as size, depth below the ground surface, orientation with respect to the search head, and type of metal. In order to provide the user with information about the target's characteristics, (e.g., to distinguish coins from nails), some metal detectors measure the phase angle between the transmitted signal and the received signal. This phase angle is typically displayed to the user as a number on an output device such as an analog meter or a liquid crystal display (LCD). Under ideal conditions this phase angle can provide the user with accurate information regarding the target.

However, in actual practice the phase angle information is materially affected by ground mineralisation and can also be affected by the target's orientation with respect to the search head. Under either of these conditions a single sweep of the search head can, with conventional displays, produce multiple phase angle readings and thereby result in an indecipherable output. In response to this problem some metal detector designers have also provided an audio output of the received signal where the tone's frequency corresponds to the phase angle of the signal and the tone's volume corresponds to the signal strength. An example of the prior art which uses a numeric LCD to display phase angle information and which also has an audio output is Maudling, U.S. Patent No. 4,868,910, assigned to the assignee of this invention. This recent prior art approach provides the user with more complete information regarding phase angle and signal strength, but suffers in that the information cannot be latched for careful analysis and it also depends upon the user's audio memory and ability to discern frequencies in order to determine the target's characteristics.

Summary of the Invention

The present invention solves the above problems by providing a bivariate visual display of two variables that are associated with a signal induced in the receive coil of a metal detector.

The two variables are preferably:

1. The receive signal's phase angle (with respect to the transmit signal) and
2. A count of the number of occurrences in which the signal amplitude exceeds a predetermined amplitude (hereinafter, the signal count) or (b) the signal amplitude.

The apparatus is preferably operable so that the user has the choice of (a) or (b). The bivariate information is displayed on a suitable graphic device such as an LCD.

The method and apparatus of the invention permit the metal detector operator to readily make a visual discrimination between valid phase angle readings that represent good target information and those that are due to extraneous, non-target magnetic field perturbations.

According to the invention there is provided a metal detector having a bivariate visual display of two signal characteristics that are representative of a target object.

The present invention further provides an improved metal detector in which (a) the phase angle between the transmit and receive signals is determined only when the signal strength exceeds a predetermined level and (b) the number of times the signal amplitude exceeds the predetermined level at a predetermined range of phase angles is counted, and then simultaneously displays both the phase angle and signal count on a visual display device.

The present invention further provides a metal detector that measures the phase angle between the transmit signal and receive signal when the signal strength exceeds a predetermined level and displays the phase angle and received signal strength simultaneously on a visual display device.

The invention and other objectives, features and advantages of the present invention will be more readily understood upon consideration of the following detailed description of an example of an embodiment of the invention taken in conjunction with the accompanying diagrammatic drawings.
Brief Description of the Drawings

FIGURE 1 is a block diagram of a portion of an exemplary metal detector circuit of the present invention. FIGURES 2a-2g show exemplary embodiments of a bivariate graphic display of the present invention showing signal information associated with a metal detector.

FIGURE 3 is an abridged flow diagram of an exemplary software routine for processing the signals associated with the metal detector.

FIGURE 4 is a flow diagram of an exemplary software routine that writes phase angle and signal count to the graphic display of FIGURE 2.

FIGURE 5 is a flow diagram of an exemplary software subroutine that selects a shorter bar character associated with the graphic display device of FIGURE 2.

FIGURE 6 is a flow diagram of an exemplary software routine that writes phase angle and amplitude information to the graphic display device of FIGURE 2.

Appendix A is a source code listing of the subroutine REPORT.

Description of a Preferred Embodiment

This invention pertains to improvements in the display of signal information generated within induction balance type metal detectors. A metal detector of this type is fully described in Maucling, U.S. Patent No. 4,868,910 which is incorporated herein by reference for purposes of providing a complete disclosure. Before proceeding to the preferred embodiment of the present invention, it is first necessary to generally describe the operation of an induction-balanced metal detector which will be done with reference to Maucling.

An induction-balanced metal detector generally has a search head with two AC coupled, electrically conductive coils: a transmit coil and a receive coil. Maucling describes a search head with three coils; transmit, receive and a feedback coil; however, the feedback coil is not relevant to the present disclosure. (See Maucling, FIGURE 1, Nos. 22, 24 and 26.) To search for buried targets, a periodic signal is applied to the transmit coil as the search head is swept over an area of ground. Under ideal conditions, i.e., proper induction balance and no magnetic field perturbations, there is no signal in the receive coil. However, when the search head passes over a target it causes a disturbance in the transmit coil's magnetic field, thereby inducing a signal in the receive coil. The transmit and receive signals are then electronically processed and applied to various output devices in an effort to measure and communicate various target characteristics. As exemplified in Maucling, the signals are processed into six components, XD, XF, YD, YF, GD and GF. Only the filtered signals XF, YF and GF are relevant to the present application. XF and YF are DC phase quadrature components of the receive and transmit signals and GF is a filtered DC signal representation of the ground mineralisation effects. (See Maucling, FIGURE 1, where 52, 56 and 78 represent signals XF, YF and GF, respectively.) From the XF and YF components, a receive signal phase angle is measured which is representative of the target's characteristics. (Maucling, FIGURES 2, 3; Col. 9, lines 35-50; and Col. 21, lines 27-50.) This phase angle information discloses characteristics such as type of metal, size, orientation of a ferromagnetic object with respect to the search head, and ground mineralisation.

FIGURE 1 of this application shows the components of Maucling's circuit which are also in the present invention. (The reference numbers in FIGURE 1 correspond to Maucling reference numbers for identical component blocks.) All the reference elements in FIGURE 1 are also represented in Maucling with the important exception of LCD 139 which is materially distinct from Maucling's LCD 138.

With reference to FIGURE 1, it can be seen that signals XF and YF emerge from respective band pass filters 42, 46 and are applied to respective track and hold circuits 50 and 54. Thereafter, signals XF and YF are applied to a multiplexor (MUX) 82. The signal GF emerges from a band pass filter 74 and is thereafter applied directly to MUX 82.

Reading a signal is a two-step process and fully described in Maucling (Col. 18, line 25 to Col. 19, line 3). In essence, the main processor 116 simultaneously commands track and hold circuits 50, 54 to hold the respective XF and YF signals so that the signals which are later sequentially input into the MUX represent XF and YF signals that are sampled at the same instant in time. The main processor 116 then directs MUX 82 to route selected signals to the MUX output in a predetermined sequence at a fixed sampling rate of approximately 7.5 milliseconds. The signals coming out of the MUX are applied to an analog-to-digital converter system 100 and then applied to the main processor 116. At this point the present apparatus and method are different from Maucling in that the main processor is arranged to write the information to LCD 139 in a suitable format using onboard software programming described hereinafter.

FIGURE 2a represents a preferred embodiment of the bivariate graphical display of the present invention showing two variables of signal information displayed on LCD 139. There is a horizontal scale that is divided
into a series of evenly-spaced divisions 205, each division represents a range of phase angles. A preferred embodiment of the present invention that is generally commercially available is a LCD having a 4 x 20 character display, which means that the horizontal axis can display 20 characters and the vertical scale can display four characters, with each character representing a range of values.

In the preferred embodiment of the display shown in each of FIGURES 2a-2g, the horizontal scale represents the relative phase angle. Each division represents a range of phase angles: where the possible range of phase angles is 180° then each division along the horizontal scale of a 4 x 20 LCD would represent a 9° range of phase angles. The vertical scale 210 represents a second variable which is either (a) a signal count or (2) an amplitude of the receive signal.

The signal count is a running tabulation of the number of times that a signal having a particular phase angle exceeds a predetermined threshold amplitude (e.g., the number of times that a signal with a phase angle between +20 and +29 exceeds a signal strength of 0.08 volts). Either the user or the main processor 116 selects the threshold amplitude to filter out weak signals. Each time a signal amplitude exceeds the threshold amplitude the associated phase angle is measured and the signal count for that phase angle is incremented.

The alternate variable displayed on the vertical scale is the amplitude of the receive signal. Only information associated with phase angles whose amplitude exceeds the predetermined threshold level is displayed.

The individual characters 212 used to represent the bivariate information are user definable characters which are bit-mapped into a five by eight matrix within the main processor 116 and downloaded to the LCD. The standard configuration displays the signal information as a bar graph, with a bar at respective phase angle ranges and the height of the bar is proportional to the signal count or signal amplitude (the bar height is zero where no signals correspond to a given range of phase angles).

FIGURES 2b-2g are examples of the LCD display when the search head encounters various buried metals. FIGURES 2b-2d represent the display in response to "good targets", that is, targets that the metal detector user may want to dig up. Good target displays are characterised by a tight grouping of bars within a narrow range of phase angles, or optimally at a single phase angle range as shown in FIGURE 2b. Additionally, good targets are characterised by groupings in the positive portion of the graph; i.e., the area between the "0" and "+(+" symbols. The exemplary embodiments of FIGURES 2b-2d also show other information on the LCD such as the VDI, which is a numeric representation of the phase angle, and a textual estimate of the target, e.g. "quarter" in FIGURE 2b.

FIGURES 2e-2g are exemplary embodiments of the display when the search head encounters undesirable (i.e., non-valuable) metal targets. These graphs display signal information having phase angles that are predominantly in the negative portion of the graph (between "0" and "(-") and which typically show a signal response at a wide range of phase angles rather than the tight grouping associated with goods targets. The bivariate display is particularly helpful in deciphering those signals that are spread across a wide range of phase angles, as is shown in FIGURE 2f. If the display were monovariate (e.g., a numeric LCD), the user would not be able to distinguish good targets from bad because the numeric LCD would be as likely to show a phase angle associated with a good target as with a bad one. But the bivariate display of the present invention shows the signal information as a "smear" across the display, thereby clearly communicating to the user that the target is not desirable.

The advantage of the bivariate display is also apparent in a comparison of FIGURE 2g with FIGURE 2d. A monovariate display would likely indicate the same phase angle for each of these targets, namely the phase angle associated with the division 250 to the immediate right of the centre because the largest bar is at that location. However the bivariate display of the present invention shows information on multiple phase angles and the good target FIGURE 2d has a bar to the positive side whereas the undesirable target FIGURE 2g has a bar to the negative side of the largest bar. A user familiar with these displays will recognise the more positive phase angles as indicative of a good target.

FIGURE 3 is an abridged software flow diagram representing the steps performed by the main processor during operation of the metal detector. A more complete flow diagram showing steps necessary for operation of a metal detector is shown in Maulting, FIGURE 11. Continuing with FIGURE 3 of the present invention, steps 302 and 304 represent channel selection and signal reading wherein the main processor 116 instructs the MUX 82 to route a selected channel to the MUX output pin. After reading the signals 304, the next step calls software subroutine PEAK 306, which determines whether signal GF has reached a local maximum value. (Subroutine PEAK is exemplary shown in Maulting FIGURE 18). A "Local maximum" is one that occurs within a predetermined period of time. When the main processor determines that GF has reached a local maximum, a flag "PK" is set. The next step, subroutine GETPHASE 308, calculates the phase of the receive signal from XF and YF and stores the result in a memory register "PHASE". (GETPHASE is exemplary shown in Maulting, FIGURE 18). After GETPHASE, the software calls subroutine REPORT 310 which checks the status of flag PK and writes the signal information to the LCD when flag PK is set. (The subroutine REPORT 310 is novel to this.
invention and has no equivalent in Maudling). Software module REPORT utilises one of two, preferably user selectable, routines AVERG (FIGURES 4 and 5) or NORM (FIGURE 6).

The REPORT subroutine checks a flag "MP" to determine whether the user has selected the display mode which shows the signal count or the signal amplitude. If the user selects the signal count display, then the subroutine REPORT will branch to a routine AVERG (FIGURE 4). Alternatively, if the user selects the amplitude display, then REPORT will branch to the routine NORM (FIGURE 6). AVERG and NORM could be subroutines, but in the preferred embodiment they are code within the subroutine REPORT.

FIGURE 4 is an exemplary flow diagram of AVERG 400 which writes signal information to the LCD. This routine determines whether a local maximum in the signal amplitude has occurred at step 410 by testing whether flag PK has been set. If PK is not set then the routine exits at 412. If flag PK is set then the routine gets the phase angle in step 420 from the memory register PHASE>. In step 425 the routine converts the phase angle into an LCD "write" address. As explained above, the preferred embodiment includes a 4 x 20 matrix LCD display device and the phase angle is represented along the 20-character axis. Therefore, the software program converts the phase angle into a "write" address corresponding to the LCD axis by multiplying the phase angle by 20 and dividing the result by 180, effectively creating 20 ranges of phase angles of nine degrees each. The routine then reads the height of the bar at the LCD address corresponding to the "write" address at step 430 and in step 435 determines whether the bar has reached a maximum height. If the bar has not reached a maximum height then the routine writes the next taller bar character in step 445. Alternatively, if the bar is at a maximum height then the routine calls FADE at step 440.

FADE 460, FIGURE 5, decrements the height of all bars that are at addresses other than the "write" address. FADE loops through 20 iterations, step 465, to read the height of the bar at each address, step 470. If the height of the bar is zero then the subroutine does nothing and loops to the next bar, step 485. If the height of the bar is not zero then the subroutine selects the next shortest bar character at step 480. The subroutine loops through all the bars until each bar other than the "write" address bar is decremented (or skipped, in the case of zero height bars) at step 485. After completing the 20 iterations the subroutine FADE returns control to AVERG which terminates at step 490.

FIGURE 6 is an exemplary flow diagram representation of the routine NORM 500. Upon entering NORM, the program first determines whether a local maximum in the receive signal has occurred at step 502 by testing for the flag PK. If flag PK is not set, the routine terminates at step 526. If flag PK is set, the program gets, at step 504, the phase angle of the receive signal from the memory register and converts the phase angle to an LCD "write" address 1 to 20, step 506, in the same manner as described above for routine AVERG. In the next step, the program runs a subroutine BYTE(GF) to calculate a compressed eight-bit datum representing the GF level which correlates to the receive signal amplitude. (BYTE is exemplarily disclosed in Maudling, FIGURE 14). Thereafter, the routine, at steps 510, 512 and 514, respectively, tests the eight-bit representation of the GF level against three preset, respectively decreasing thresholds designated thresholds 1, 2, and 3. If the GF level is greater than the first threshold 510, then the routine selects all four segments of the bar at step 516. If the GF level is less than threshold 1 but greater than the next lowest threshold 2, step 512, then the routine selects three of the four bar characters at step 518. If the GF level is less than threshold 2 but greater than the lowest threshold 3, step 514, then the routine selects two bar characters at step 520. If the GF level is less than threshold 3 then the routine selects one bar character at step 522. The routine then writes the information to the "write" address at step 524 and exits the subroutine at step 526.

The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognised that the scope of the invention includes and provides any metal detector or method incorporating any novel constructional or operational feature, step or process disclosed herein or in the accompanying drawings.
APPENDIX A

2500 A.D. 8805 CROSS ASSEMBLY - VERSION 1.01a

INPUT FILENAME : REPORT.HMN
OUTPUT FILENAME : REPORT.OBJ

NAM REPORT 07 FEB 89/modified 7/28/89 MDR

******************************************************************************
#OUT:TARGET DATA DISPLAYED IN AUDIO AND LCD.
#CRITERION FOR LEARN = PX
#CRITERION FOR AUDIO = SFLEV

******************************************************************************
PUBLIC REPORT
EXTERN AUDIO ;SDK & SOUT TO AUDW
EXTERN DISPLAY ;DISCRIMINATE FILTER->SDK
EXTERN SET,CLR ;LEARN ROUTINES
EXTERN VDI,VDIAV,AVCOUNT,DISSTAB,SO,SCOUNT,ITONE
EXTERN PAEGO STATE,PAEGO SHOT,PAEGO DISPTR,PAEGO KEY
EXTERN PAEGO STAT ;=L,GREJ,6=LRMACC IN
12=PK,3=TRIS,F=DISC IN
10=DK OUT
EXTERN PAEGO FLAGA ;3=DMN:SET IF ACCEPT OUT
14=DK:SET IF DISC ON OUT
12=ATH IN
EXTERN PAEGO FLAGB ;6=DMN OUT
14=SIGN BIT INT
5=ATIME RUNNING INT
EXTERN PAEGO FLASP ;10=ac overload
EXTERN PAEGO SFLEV ;DATA FROM PEAK IN
EXTERN PAEGO GFAMP ; abs(compressed(SF))
EXTERN PAEGO DISLEV ;DISC. DATA TO AUDIO OUT
EXTERN PAEGO ACENS ;used FOR SHIFTS IN
EXTERN PAEGO PHASE ;SB IN
EXTERN PAEGO PHRAC
EXTERN PAEGO TEMN ;STASH INT
EXTERN PAEGO OPTST ;RAW TEST ADDRESS IN
EXTERN PAEGO ATIME ;RECOVERY HOLD OFF INT
EXTERN PAEGO RECV ;user adj. hold off
EXTERN PAEGO VBISENS,PAEGO FADERATE,PAEGO FADECOUNT
EXTERN PAEGO SCREJ
EXTERN PAEGO SISBAL
EXTERN PAEGO STATABL
EXTERN PAEGO TSREQ
EXTERN PAEGO FLAG4
EXTERN DIVIDE
EXTERN CLORDATA,FADE,LABEL,CLVDOI

******************************************************************************
REPORT 3BCLK J,STAT,SEARCH 160 IF NO TRIGGER

******************************************************************************
; TRIGGER PRESSED (PINPOINTING MODE)

******************************************************************************
0000 07 00 79
LDA DISPTR
CMP #28
49 0007 26 49  BNE JNR
50 0009 36 70  LDA SIGMA
51 0006 44  LER
52 000C 44  LGRA
53 000D 40  NEGA
54 000E A8 14  ADD #29
55 0010 97  TAX
56 0011 36 0C  LDA TREQ
57 0012 A0 04  SUB #4
58 0015 2A 02  BPL SCALE2
59 0017 40  NEGA
60 0018 5C  INCI
61 0019 27 04  SCALE2 BEQ SCALE3
62 001A 5C  INCI
63 001C 4A  DECA
64 001D 20 FA  BRA SCALE2
65 001F 0A 07 05  SCALE3 BSET %,STABALL,SCALE4
66 0022 5C  INCI
67 0023 5C  INCI
68 0024 5C  INCI
69 0025 A6 00  SCALE4 LDA @HOT
70 0027 2A 01  BPL SCALEIT
71 0029 4F  CLR
72 002A A1 78  SCALEIT CMP #120
73 002C 25 04  BLD SCALIT2
74 002E A6 11  LDA #19
75 0030 20 08  BRA SHOWIT
76 0032 42  SCALIT2 MUL
77 0033 BF 00  STI TEMA
78 0035 AE 07  LDI #7
79 0037 34 00  SCLOOP LSR TEMA
80 0039 46  RORA
81 003A 5A  DECI
82 003B 26 FA  BNE SCLOOP
83 003D A1 13  SHOWIT CMP #19
84 003F 23 02  BLS INDEXK
85 0041 A6 13  LDA #19
86 0043 97  INDEXK TAX
87 0044 A6 02  LDA #2
88 0046 D7 00 OF  STA DISTABL15,1
89 0049 BF 00  STI TEMA
90 004A 5C  MRKLOOP INCI
91 004C A3 14  CPX #20
92 004E 24 19  BNS BARIT
93 0050 B6 00 OF  LDA DISTABL15,1
94 0053 A1 C0  CMP #32
95 0055 27 09  BEQ BARIT
96 0057 A6 A1  LDA #41H
97 0059 D7 00 OF  STA DISTABL15,1
98 005C A3 13  CPX #19
99 005E 25 3B  BLD MRKLOOP
100 0060 5F  BARIT CLR
101 0061 A6 02  LDA #2
102 0063 33 00  BARLOOP CPX TEMA
103 0065 27 05  BEQ JCTST
104 0067 D7 00 OF  STA DISTABL15,1
105 006A 5C  INCI
00E8 20 Fa       BRA BARLUDP
00ED B6 00      DEPTST LDA PHASE
00F0 02 08 60    BASET 1,STATTAB+8,SIGN?
00F3 00 00      JNR JMP WRITE ;UPDATE AUDIO & STM
00F6 00 00      SETFADE LDA #16
00F9 80 00      SUB FADERATE ;1 (min) - 15 (max)
00FA 48         LELA
00FB 48         LELA
00FC 48         LELA
00FD 48         LELA
1000 57 00      STA FADECOUNT
1006 07F   81    RTS
118                  **************************************
119                  TRIGGER RELEASED (SEARCH MODE)  
120                  **************************************************
121
1100 0080 01 00 00  SEARCH BRCLR 0,STATE,NOFADE
1103 0083 3D 00    TST FADERATE
1104 0085 27 09    BNE NOFADE
1105 0087 3A 00    DEC FADECOUNT
1106 0089 26 05    BNE NOFADE
1107 008B AF 00    BSR SETFADE
110D 000D C0 00 00  JSR FADE
1111 007C DB 00 00  NOFADE JSR DISFLT ;UPDATE DOK
111A :check for valid time to do peak processes
111E 0073 05 00 05  BRCLR 2,STAT,NOTPK ;SO,NOT PEAK
1121 0076 07 00 02  BRCLR 3,FLAGA,NOTPK ;SO,NOT DOK
1124 0099 20 12    BRA PEAK
1127 007B C0 00 00  NOTPK JSR LABEL
112F 009E C0 00 00  LDA VDI
1133 00A1 A1 64    CMP #100 ;if overload or low bat showing
1137 00A3 24 05    BMS JMP ;..don't defeat label update
113B 00A5 A6 66    LDA #102 ;"no label" code
113F 00A7 C7 00 00  STA VDI
1142 00A8 CC 01 70  JMP JMP NOTPK2
1142                  **************************************
114E                  PEAK PROCESSES: DO AT PEAK OF EACH WAVE  
115B                  **************************************************
1144 00AD 02 0A 08  PEAK BRSET 1,STATTAB+10, NOCLEAR ;test single sweep/accum.
1147 00B0 01 00 05  BRCLR 0,FLAGS, NOCLEAR
114A 00B3 11 00    BCLR 0,FLAGS
114D 00B5 C0 00 00  JSR CLRDATA
1150 00B8 AD 88    NOCLEAR BSR SETFADE
1156 008A B6 00    LDA PHASE
1159 008C C7 00 00  STA VDI
115C 008F C7 00 00  STA IDTONE
115F 00C2 08 08 00  BRCLR 5,STATTAB+8,SIGN? ;skip test if vis. disc. off
1163 00C5 00 00 0A  BRSET 0,STAT, SIGN? ;accept targ.?
1166 00C8 CD 00 00  JSR CLVDO1
1169 00CB A6 67    LDA #103
116C 00CD C7 00 00  STA VDI
116F 00E0 20 37    BRA SPECTM
1173 00E2 2A 00    SIGN? BPL POSVDI
117B 00E4 40      NESG
117F 00E5 AE 20    LDR #20H
1183 00E7 CF 00 01  STI DISTTAB+1
1186 00E9 20 05    BRA DOWNUM
REPORT  07 FEB 87/scrolled 7/23/89  10 A2

161 00DC  AE 10  POSVDI  LDX    #12
164 00DE  DE 00  DL  STA,   DISTABL+1
165 00DE  AE 0A  DVMARR  LDX    #10
166 00DE  CD 00  JO  JMB,   DIVIDE
167 00DE  AB 20  ADD    #3FH
168 00DE  C7 00  V2  STA,   DISTABL+2
169 00EE  4F  TAX
170 00EE  AB 20  ADD    #3FH
171 00EE  C7 00  V3  STA,   DISTABL+3
172 00F1  AB 2E  LDA    #2EH
173 00F1  C7 00  V4  STA,   DISTABL+4
174 00F6  56 00  LDA    PHRAC
175 00F6  AB 20  ADD    #30H
176 00F6  C7 00  V5  STA,   DISTABL+5
177 00FF  AB 1C  LDA    #2B
178 00FF  87 00  STA    DISPTR
179 0101  1F 00  SCLR    7,FLAG4
180 0101  07 00  03  BCLR    3,STAT,SPECTM
181 0106  CC 01  EC  JMP    WRITE
182 0109  5F  SPECTM,  CLRZ
183 010A  2A 00  LDA    PHASE
184 010C  AB 60  ADD    #86  jmlize to -96 00
185 010E  87 00  STA    TEMA
186 0110  4F  CLEZ
187 0111  AB 0A  VLOOP   ADD    #10
188 0113  B1 00  CMP    TEMA
189 0115  24 03  SWS0    DISBAR
190 0117  5C  MC
191 0118  20 07  BRA    VLOOP
192 011A  04 0A  21  DISBAR  BASET    2,STATTABL+10,AVERS
193
194  ;"normal" mode -- scale bar height by gf amp.
195 011D  86 00  LDA    SFAMP
196 011F  2A 01  BPL    COMP4A
197 0121  AB  NEA
198 0122  A1 0B  COMP4A  CMP    #6BH
199 0124  24 04  BLO    COMP4C
200 0126  AB 02  LDA    #2
201 0128  20 05  BRA    STASH
202 012A  01 0B  COMP4D  CMP    #4BH
203 012C  24 04  BLO    COMP4D
204 012E  AB 03  LDA    #3
205 0130  20 0D  BRA    STASH
206 0132  A1 0B  COMP1B  CMP    #3BH
207 0134  24 04  BLO    SHORT
208 0136  AB 04  LDA    #4
209 0138  20 05  BRA    STASH
210 013A  AB 0F  SHORT  LDA    #5FH
211 013C  20 21  BRA    STASH
212
213  ;"average" mode -- count hits and show distribution
214 013E  D6 00  0F  AVERS  LDA    DISTABL+15,1
215 0141  A1 10  CMP    #20H
216 0143  16 04  BNE    COMP5F
217 0145  AB 05  LDA    #5FH
218 0147  20 16  BRA    STASH
219 0149  A1 0F  COMP5F  CMP    #5FH

9
REPORT 07 FEB 29:modified 7/25/09 MBR

LEARN ;modify memory based upon phase
SRCLR 6,STATTBL+10,LRN1=05 NOT LANREJ
VSR SET
SRA LANEND
SRCLR 5,STATTBL+10,LRNEND=05 NOT LANACC
VSR CLR
LARNEND
MOTPtx

* THE FOLLOWING OCCURS EVERY CYCLE *

* WEIGHT SFLVEY FOR NORMAL OR HIGH GAIN *
* IM1=SFLVEY (0-128) *
* OUT=A,TERM=WEIGHTED SFLVEY (0-128) *

LDA SFLVEY
BEG WOFEND ;STAT AT 0 IF 0
LDR ACSENS
CPY #65
LSR WOFEND
SNE WOFEND
INCA
WOFEND STA TEMA

* ATIME CONTROL SYSTEM *
* IM2,FLAGS=ATH) RESETS ATIME *
* OUT=5,FLAGS SET IF ATIME RUNNING *

SCLR 5,FLAGS ;ASSUME NO ATIME
SCLR 2,FLAGS,NOATH

if ath detected, reset atime with app. value
LDA #30
SUB RECOV ; 40 (max) - 1 (min)
LSRA
STA ATIME
NOATH TST ATIME ;CHECK IF RUNNING
SNE DECIT
SET 0,FLAGS
VRA ATEND
DECIT DEC ATIME ;SERVICE ATIME &
EP 0 580 396 A2

REPCAT 07 FEB 89/modified 7/28/89 MGR

277 0198  qTEND
278
279  ; DECREASE DISLEV UNLESS ATIME
280  ; OUT:DISLEV=0 IF ATIME OVER
281
282  ; skip decrease if atime running
283  019B  0A 00 96  BRSET 3,FLAGB,DECEND ;GO IF ATIME
284  019B  27 00  ADR DISLEV
285  019D  2A 02  SPL DECEND
286  019F  3C 00  INC DISLEV ;FORCE WES CONVERGENCE
287
288  01A1  DECEND
289
290  ; skip add if not atime
291
292
293  01A4  0B 00 37  BRCLR 5,FLAGB,ADDEND
294
295
296  01A6  86 00  ADDUP LDA DISLEV
297  01A6  4B 09  ADD #60H ;#=DISLEV (GB)
298  01AB  00 00 16  BRSET 0,STAT,ACC ;GO IF ACCEPT
299
300  01A8  00 00 0E  BRSET 0,DISLEV,SUBIT ;test ac overload
301  01AE  06 00 08  BRSET 7,PHASE,SUBIT ;don't bias pos. phase responses
302  01B1  97  TAX ;x has dislev
303  01B2  26 00  LDA BCREJ ;# (min) - 20 (max)
304  01B4  44  LSR ;0 -> 10
305  01B5  B1 00  CMP TEMA ;clip?
306  01B7  25 02  SLD GIFX
307  01B9  97 00  STA TEMA ;clip above min. neg. excursion
308  01BB  9F 00  GIFX TAX
309  01BC  90 00  SUBIT SUB TEMA ;A=DISLEV-ADJ GIFX (GB)
310  01BE  24 17  BCC NOCLIP ;CLIP IF OVERFLOW
311  01C0  4F  CLRA ;CLIP # 0
312
313  01C1  00 00 0D  ACC BRSET 0,DISLEV,ADDIT ;test ac overload
314  01C4  97  TAX ;x has dislev
315  01C5  A6 18  LDA #24 ;bc rej: 1 (min) - 20 (max)
316  01C7  B0 00  SUB BCREJ ;25 - 4
317  01C9  48  LSLA ;#6 (min) - 8 (max)
318  01CA  B1 00  CMP TEMA ;clip?
319  01CC  22 02  BMI GIFX2
320  01CE  87 00  STA TEMA ;clip below max. pos. excursion
321  01D0  9F 0F  GIFX2 TAX
322
323  01D1  5B 00  ADDIT ADD TEMA
324
325  01D3  24 02  BCC NOLF3 ;CLIP IF OVERFLOW
326  01D5  46 FF  LDA #0FFH
327  01D7  NOLF3
328
329  01D7  A0 00  SUB #00H ;CONVERT SB
330  01D9  35 00  STA DISLEV ;POSSIBLY REDUNDANT
331  01DA  ADDEND
332
333  ; KIG UP DON AND ODD FROM DISLEV
* IN:  DISLEV  
*OUT: ODD=1 IF 'DISLEV'; VOISEN=DATA PRESENT;  
*OUT: ODN=1 IF DISLEV = 0 (ACCEPT)  

```
028 0130 18 00  
BSET 4,FLAGA ;ODN (SET IF ACCEPT)  
037 0100 17 00  
SCLR 3,FLAGA ;OOD (SET IF DISC ON)  
040 012F 2A 03  
BPL  RPT2 ;GO IF PLUS  
041 01E1 40  
NEGA  
042 014E 19 00  
SCLR 4,FLAGA ;OOD CLEAR=REJ  
043 01E4 BB 00  
RPT1 ADD VOISEN ;VOL sens.: 1 (min) - 99 (max)  
044 01E6 41 04  
CMP $100  
045 01EB 23 02  
BLO  RPT2 ;GO IF >THRESHOLD  
046 01EA 1A 00  
BSET 5,FLAGA ;OBD: ENABLE DISCRIM.  
047 01EC  
RPT2  

* ALWAYS UPDATE AUDIO AND DISPLAY.  

WRITE  
JSR  AUDIO  #DO AUDIO  
RTS  #END OF REPORT  
END
```
<table>
<thead>
<tr>
<th>Cross Reference Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGC 01G1 : 298</td>
</tr>
<tr>
<td>AGENS EXTERN : 252</td>
</tr>
<tr>
<td>AGEND 0108 : 294</td>
</tr>
<tr>
<td>AGIT 0101 : 312</td>
</tr>
<tr>
<td>AGDUP 0144 : 274</td>
</tr>
<tr>
<td>ATIME EXTERN : 270</td>
</tr>
<tr>
<td>AUTO EXTERN : 252</td>
</tr>
<tr>
<td>AVECOUNTER EXTERN :</td>
</tr>
<tr>
<td>AVR50 013E : 192</td>
</tr>
<tr>
<td>BARIT 0060 : 92</td>
</tr>
<tr>
<td>BARLOOP 0063 : 106</td>
</tr>
<tr>
<td>SCREW 0106 : 316</td>
</tr>
<tr>
<td>CLR EXTERN : 237</td>
</tr>
<tr>
<td>CMODATA EXTERN : 147</td>
</tr>
<tr>
<td>CLRVI EXTERN : 154</td>
</tr>
<tr>
<td>COMPO 0122 : 203</td>
</tr>
<tr>
<td>COMPO 0151 : 220</td>
</tr>
<tr>
<td>COMPO 012A : 199</td>
</tr>
<tr>
<td>COMPET 0149 : 216</td>
</tr>
<tr>
<td>COMPA 0122 : 196</td>
</tr>
<tr>
<td>COMPTST 004D : 103</td>
</tr>
<tr>
<td>DECOD 0101 : 285</td>
</tr>
<tr>
<td>DECR 0194 : 272</td>
</tr>
<tr>
<td>DISBAR 011A : 189</td>
</tr>
<tr>
<td>DISFLY EXTERN : 129</td>
</tr>
<tr>
<td>DISLEV EXTERN : 204</td>
</tr>
<tr>
<td>DISPTR EXTERN : 47</td>
</tr>
<tr>
<td>DIETABLE EXTERN : 88</td>
</tr>
<tr>
<td>DIVIDE EXTERN : 186</td>
</tr>
<tr>
<td>DOYNUM 0061 : 162</td>
</tr>
<tr>
<td>FADE EXTERN : 128</td>
</tr>
<tr>
<td>FADECOUNT EXTERN : 116</td>
</tr>
<tr>
<td>FADERATE EXTERN : 111</td>
</tr>
<tr>
<td>FLAG4 EXTERN : 145</td>
</tr>
<tr>
<td>FLAB EXTERN : 132</td>
</tr>
<tr>
<td>FLAG1 EXTERN : 288</td>
</tr>
<tr>
<td>FLABP EXTERN : 300</td>
</tr>
<tr>
<td>FSCNT EXTERN : 1</td>
</tr>
<tr>
<td>SFAMP EXTERN : 195</td>
</tr>
<tr>
<td>SFLEV EXTERN : 250</td>
</tr>
<tr>
<td>SFIX 01BB : 506</td>
</tr>
<tr>
<td>SFIX2 01DD : 519</td>
</tr>
<tr>
<td>SHOT EXTERN : 69</td>
</tr>
<tr>
<td>SIDEC EXTERN : 151</td>
</tr>
<tr>
<td>SODC EXTERN : 214</td>
</tr>
<tr>
<td>SSTRK EXTERN : 74</td>
</tr>
<tr>
<td>SSTRS EXTERN : 134</td>
</tr>
<tr>
<td>隨後 0162 : 214</td>
</tr>
<tr>
<td>.SIW 016A : 215</td>
</tr>
<tr>
<td>.SRMEND 0170 : 226</td>
</tr>
</tbody>
</table>
Claims

1. A metal detector having induction balanced transmit and receive coils wherein an electronic signal supplied to said transmit coil generates a receive signal in said receive coil when said coils are subjected to local magnetic field perturbations, characterised by:
   (a) first variable calculation means (116) for determining phase angle values associated with said receive signal;
   (b) second variable calculation means (116) for determining second variable values associated with said receive signal; and
   (c) a visual display (139) having a plurality of display unit addresses wherein each address corresponds to a range of phase angle values for displaying said phase angle values and respective said second variable values.

2. The metal detector of Claim 1 wherein said second variable value is representative of a count of a number of times that the receive signal at a particular phase angle exceeds a predetermined amplitude threshold.

3. The metal detector of Claim 1 or 2 wherein said second variable value is representative of a signal amplitude associated with said receive signal.

4. The metal detector of Claim 1, 2 or 3 wherein said visual display (139) is a liquid crystal display.

5. The metal detector of Claims 1, 2, 3 or 4 wherein said first and second variable calculation means are software routines performed by a microprocessor (116).

6. A method of displaying signal information on a display unit (139) associated with a metal detector having a receive signal, characterised by the steps of:
   (a) establishing a plurality of display unit addresses wherein each said address can have display characters;
   (b) detecting a local maxima of an amplitude associated with said receive signal;
   (c) determining and quantifying a phase angle associated with said receive signal when said local maxima is detected;
   (d) converting said phase angle into a write address associated with one of said display unit addresses;
   (e) determining a second variable associated with said receive signal;
   (f) reading a display character at said write address; and
   (g) altering the display character at said write address to reflect said second variable.

7. The method Claim 6 wherein step (b) comprises detecting only local maxima that exceed a predetermined threshold.

8. The method of Claim 6 or 7 wherein said second variable is a count of the number of times the receive signal at a particular phase angle exceeds an amplitude threshold.

9. The method of Claim 6, 7 or 8 wherein said second variable is a signal amplitude associated with said receive signal.

10. The method of Claim 6, 7, 8 or 9 further comprising the step of determining that said display character at said write address cannot be altered to reflect said second variable and then altering display characters at all addresses having displaying characters except said write address.
Fig. 2a

VDI: 85.5
(-) +++++-0-------(+)  
GOOD TARGET

Fig. 2b

VDI: 87.0
(-) +++++-0-------(+)  
GOOD TARGET

Fig. 2c

VDI: 19.8
(-) +++++-0-------(+)  
GOOD TARGET

Fig. 2d

VDI:  
(-) +++++-0-------(+)  
IRON

Fig. 2e

VDI:  
(-) +++++-0-------(+)  
IRON ALLOY

Fig. 2f

VDI:  
(-) +++++-0-------(+)  
NICKEL/RING

Fig. 2g

VDI:  
(-) +++++-0-------(+)  
FOIL
Fig. 3

1. OPR (ABBR.)
2. SELECT CHANNEL
3. READ SIGNALS
4. PEAK
5. GET PHASE
6. REPORT
Fig. 4

1. **AVERG**
2. **HAS GF PEAK OCCURRED?**
   - **NO** → **END**
   - **YES** → **FIND PHASE FROM XF, YF**
3. **CONVERT PHASE (-95 TO +95) TO LCD ADDRESS (1 TO 20)**
4. **READ HEIGHT OF BAR AT LCD ADDRESS**
5. **HAS BAR REACHED MAXIMUM HEIGHT?**
   - **NO** → **SELECT NEXT TALLEST "BAR" CHARACTER**
   - **YES** → **JUMP TO SUBROUTINE FADE**
6. **SEND TO SELECTED LCD ADDRESS**
7. **END**
FADE

FOR LOOP = 0 TO 19

READ HEIGHT OF BAR AT OFFSET (LOOP) INTO DISPLAY TABLE

DOES HEIGHT = 0?

SELECT NEXT SHORTEST "BAR" CHARACTER

LOOP UNTIL DONE

Fig. 5
Fig. 6

1. NORM
   2. PK SET?
      3. YES → READ PHASE
         4. NO

4. CONVERT PHASE TO LCD ADDR.
5. BYTE (GF)
6. GF > THRESHOLD 1?
   7. YES
      8. SELECT ALL FOUR BAR CHARACTERS
      9. NO → GF > THRESHOLD 2?
         10. YES → SELECT THREE BAR CHARACTERS
             11. NO → GF > THRESHOLD 3?
                12. YES → SELECT TWO BAR CHARACTERS
                    13. NO → SELECT ONE BAR CHARACTER

14. WRITE TO LCD
15. END

16. 500
17. 502
18. 504
19. 506
20. 508
21. 510
22. 512
23. 514
24. 516
25. 518
26. 520
27. 522
28. 524
29. 526