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AI-Based Diagnostic Shell

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ABSTRACT

This paper datails the design and implementation of an AI-based diagnostic shell. The shell has a user-interface which takes in the complaint and aids the user throughout the consultation. The 'expert knowledge' is acquired and encoded in the form of 'IF-THEN' rules. The control mechanism routes through the rules chaining first backwards to identify a fault and then forwards to confirm it. Explanation facilities have been provided to enable the user query the reason for any question asked, a facility to go back and re-answer any previous question, and a trace and explanation of the path of reasoning.

This shell was developed and first used for the diagnosis of a digital exchange. It was then applied for the fault-finding of the moving target indicator used in the radar.

1. INTRODUCTION

It was found that most of the complex equipment developed for use in the battlefield, required skilled and trained personnel for their use and maintenance. An enormous amount of time and effort would be required to train an unskilled user to handle these equipment. An 'expert system' was found to be a panacea in most of these situations. So a knowledge-based shell was developed to capture the knowledge of the expert in a software program.

It is basically a production system consisting of production rules, a control system and a database. The knowledge base – the domain – is coded in terms of about a hundred IF-THEN Rules. The rules are of the form :

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IF (Antecedent 1) THEN (Consequence 1)
(Antecedent 2) (Consequence 2)
"

If the antecedents are satisfied the rule is fired and the corresponding consequence is asserted. This in turn creates the premise for the succeeding rule, and the process continues until the termination condition is satisfied. The rules chain together and define the AND/OR diagnostic tree. The knowledge base also has a database which is operated on for the help and explanation utility. The control mechanism routes through the rules to reach the goal.

This Artificial Intelligence (AI)-based approach was found suitable for many reasons. Where expertise is scarce, the knowledge was acquired from one/more experts. The 'rules-of-thumb' or heuristic knowledge was conveniently encapsulated as units of information in the form of rules. As opposed to a diagnostic flow chart the system carries on an interactive session with the user, asking him focussed questions and offering help throughout the session. The system gives sound advice and at the end of the consultation gives the user a peep into its 'thought-process'. Considering the tremendous expense and effort involved in educating an unconnected and uninformed user, the economics of such a system is found to be good.

2. THE DIGITAL EXCHANGE

It is a microprocessor controlled automatic digital exchange. It works on TDM principle and provides communication for twenty voice subscribers. The structural diagram of the exchange is shown in Fig. 1. A line circuit and a codec set per subscriber

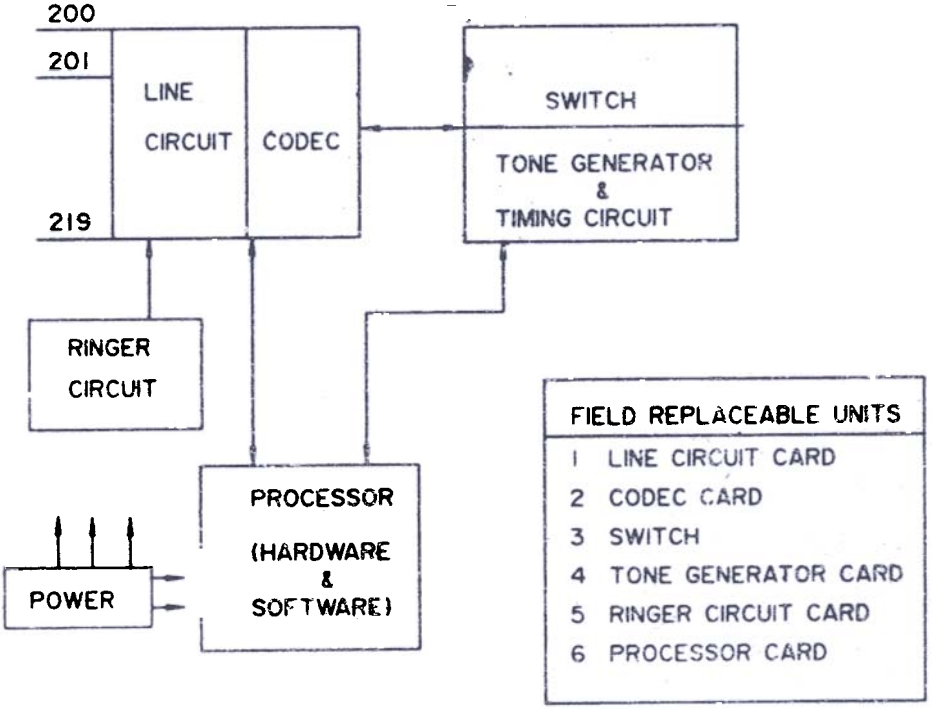


Figure 1 Structural model of the exchange.

does the analogue to digital conversion. The switch controlled by the processor does the time slot interchange. The tone generator, timing circuit and ringer circuit provide the necessary timing and supervisory tones like dialtone, ring back tone, busy tone, etc. These tones are easily detectable, and therefore, primarily used to give an indication of the health of the system. This exchange, to be used by the army, was found to require diagnosis upto the field replaceable units, to put it back to working condition in the field area. The different sub-units have been conveniently accommodated in separate cards/printed circuit boards and these constitute the field replaceable units. They are (a) line card, (b) codec card, (c) switch card, (d) tone-generator card, (e) ringer circuit card, and (f) processor card. Apart from this, the power supply is also a separate unit to be tested.

3. THE USER INTERFACE

The shell is provided with a user-friendly interface. The user is to interact with the system in simple English. He is to enter one complaint at a time. The system has some ability to comprehend the complaint and check for its validity.

The shell has been initially keyed-in with a domain-limited dictionary by the expert. On receiving a complaint, it looks for the main keywords alongwith the subsequent keywords (as opposed to tallying complete sentences). On referring the dictionary, the complaint is converted to a coded pattern. This pattern is then checked against permissible patterns (again available in the dictionary), to declare whether the complaint is valid or not.

The database is initially entered with (a) the keywords and their respective codes (R1), and (b) the set of valid code patterns (R2). An excerpt, simplified from the actual database is given below :

```
(DEFUN R1 ()
(SETQ R1 '(
(CROSSTALK 5) (CROSS-TALK 5) (CROSS 5)
(WRONG 8) (NO 8) (NOT 8) (FAULTY 8) (FAILURE 8) (FAULT 8)
(INCORRECT 8) (BAD 8) (ABSENT 8)
(PRESENT 10) (FOUND 10) (OBTAINED 10) (HEARD 10)
(NO 13) (NUMBERS 13) (NUMBER 13)
(TALK 14)))
SETQ R2 "(
(5) (5, 10) (5 14) (5 14 10) (8 13) (8 13 10))))
```

A complaint expressed as

```
(I GET SOME CROSS-TALK) (5)
(WRONG NUMBER OBTAINED) (8 13 10)
(CROSS-TALK PRESENT) (5 14 10)
```

would yield a valid response (The fact that an unskilled operator often reports cross-talk for wrong number has also been considered)

(NO CROSS-TALK) (8 5)
(CROSS-TALK NOT ABSENT) (5 8 8)

would yield an invalid response and offer help. If the complaint is valid the operator is permitted to carry on. Else the system assists even an unacquainted user by providing the list of valid complaints for him to choose from. The actual consultation is given in Appendix A. The consultation carries on as a question and answer session. At every point the uninformed operator is offered help to enable him comprehend the question better.

4. THE CONTROL MECHANISM

The method of reasoning is structured, essentially classifying the rules into two types; (a) the testability rules deciding the testability of the system, and (b) the strategy rules deciding the strategy for fault diagnosis. The first set eliminates the most commonly occurring faults. The second set does a heuristically guided depth–first search. Examples of these rules are given in Appendix B.

It has been found that when the system fails, the most typical faults trace back to the power supply units. So whatever be the fault, the first set of rules are queried to rule out faults in this area. In the subsequent runs the user is given the option of skipping these, if they have been checked in the recent past.

The user is then asked to key in the complaint. On validating the complaint, he is asked questions regarding the status of the system. Typically the user is asked to look for a symptom that is easily detectable. In the exchange, for example, check for one/more tones, make a call to a contiguous subscriber and check for ringing tone, check for linefeed on the phone would be asked.

The system chains backwards from symptoms to fault, i.e., depending on the symptoms entered, a plausible goal is hypothesised, (as indicated by the expert when giving his experience). The knowledge is incorporated in the knowledge base by giving the more probable goal a lower rule number than the less probable one, thereby considering the former before the latter. Backward or goal-directed chaining has been chosen since, in this direction, the branching factor is low and the penetrance factor is high, and therefore is well suited to this problem. An irrevocable control strategy has been implemented. Task dependent information on heuristic information, as obtained from the expert has been incorporated. And the search strategy used is the heuristically guided depth-first search method – coursing from the more probable to the less probable faults. Hence the least expected fault will take the maximum time to diagnose. The hyptotheses are persued in a predefined order yielding a dialogue directed by the system. The diagnostic process is shown in Fig. 2.

We take an example of a 'no dialtone' complaint to illustrate the operation of the system. On validation of the complaint the control mechanism is activated. It first establishes the testability of the system by checking the power supply and timing units. If no faults have been detected here, the system progresses like the expert, to aid the unskilled user. Assume that the reported line does not get dialtone and speech, but the other processor functions are normal. The system would query for linefeed and

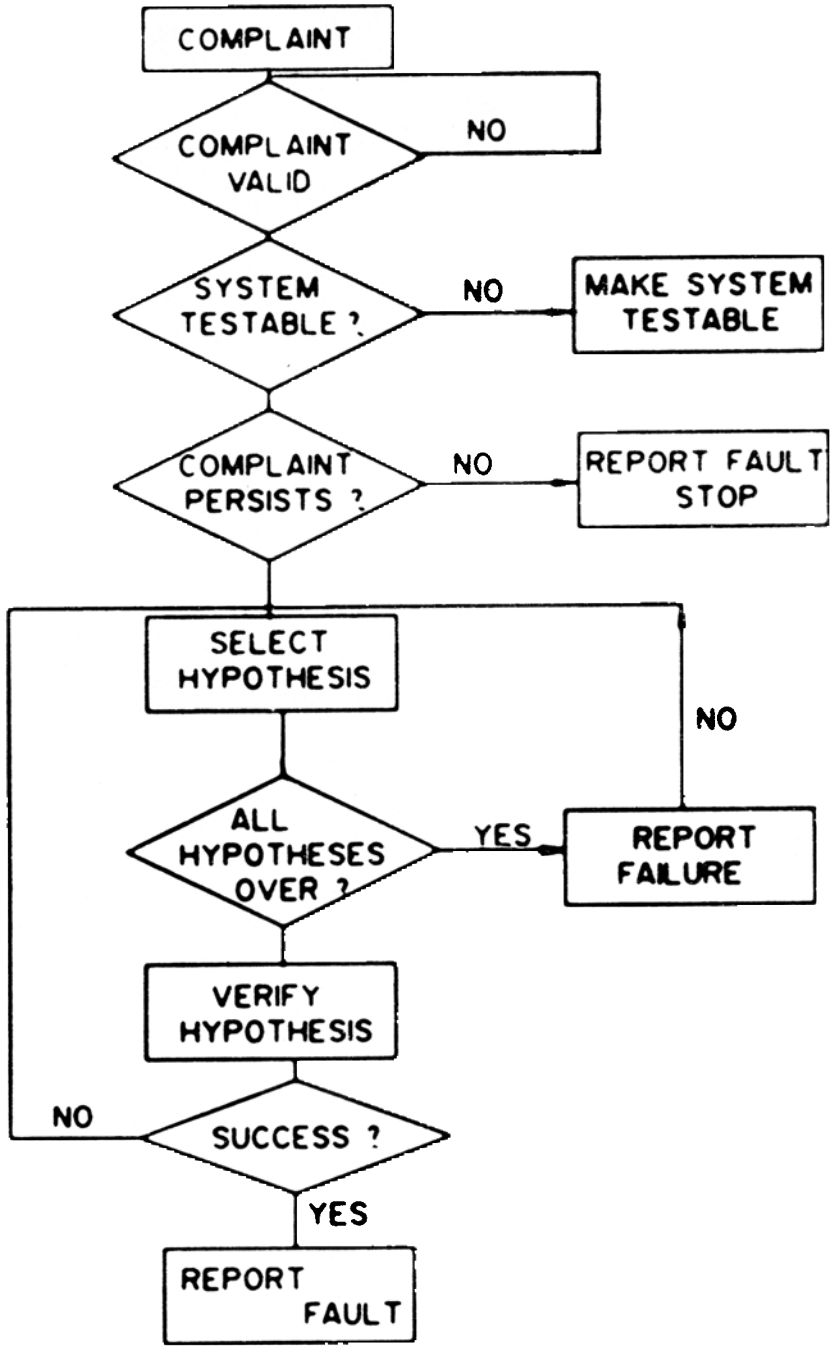


Figure 2. Diagnosis process – program flow.

continuous ringing and eliminate a line card failure. Then on suspecting a codec failure, it would check the dialtone in three contiguous subscribers. Further on eliminating this, it would check for absence of the supervisory tones and call processing functions and eliminate the tone-generator card and finally zero-in on the switch card.

On reaching a probable goal the system chains forward along a different path, searching for other symptoms indicative of the same fault. It then asks the user to look for those symptoms to confirm the fault; thereby re-enforcing the conclusion arrived at or reducing the probability of the previous conclusion and suggesting an alternative one. The certainty of a particular result is as fixed by the expert. It is classified into three broad categories – probably faulty, most probably faulty and

definitely faulty (with increasing order of certainties). The concept of backward and forward chaining along with sample consultation is given in Appendices C and D.

5. EXPLANATION FACILITIES

The shell provides explanation facilities to cater to both the unskilled and knowledgeable users. In addition to aiding the user it provides a peep into the operation of the control mechanism.

For an intelligent user who does not understand the rationale behind asking a particular question, the 'WHY' facility has been provided . In response to Why (a question has been asked) the current rule is displayed in the format :

To trigger the following rule :-
IF (Antecedent 1, Antecedent 2)
THEN (Consequence 1)
ELSE (Consequence 2)

A recall facility has also been incorporated. A user typically finds the need to modify the answer to any previous question. When the user opts to go BACK, the system responds asking him whether he needs to go back to the previous question or any other. In case of the latter he is provided with the option to take a trace of the session, to view the question-answer module and then given the question number from which he wishes to re-answer. The question indicated is queried again and from there on the consultation is resumed.

Finally on completion of the consultation session, the shell offers a trace facility and an explanation facility. The former gives the path of reasoning in a question-answer module (this was also used by the BACK). The latter gives alongwith the question-answer module, an explanation for having arrived at a partial or final conclusion. In addition, the explanation gives ways of confirming the fault arrived at, i.e., the path of forward chaining.

For the explanation facility, the shell maintains an association list. The association list consists of pairs (question number; answer given) of all the questions asked. The question number corresponds to the number of the rule being tried (rule no.) and the pairs are maintained in the list in the order in which the questions are asked. For example, consider the association list ((Q3 Y) (Q10 Y) (Q12 N) (Q2). . . . .). Here Q3 represents the first question,i.e., question 3 which corresponds to rule 3 which is being tried. Rule 3 has been fired successfully (Y) and it has created the premise for firing rule 10. The current question being asked is Q2 corresponding to rule 2, and is waiting to be answered.

Now, for the WHY facility the rule 2 is read out by the shell. The BACK utility goes back to the required question and erases the list following it. The TRACE facility reads out the rules, with their corresponding answers given from the list.

6. APPLICATION TO THE MTI DOMAIN

6.1 The MTI

The Moving Target Indicator (MTI) in the radar differentiates between moving and stationary objects. It suppresses fixed echoes while retaining moving echoes. This is done by comparing the the phase of the transmitted pulse with that of the echoes at each transmission. The phase detection is also simplified at an IF.

PF energy from the STALO is fed to an AFC mixer, which in turn gives an IF as output. For a continuous comparison, as mentioned earlier, a coherent oscillator is employed. It retains the phase of the transmitter and is fed to the phase detector.

The echo energy through the TR and the STALO feed the signal mixer. The resultant IF from the signal mixer is amplified and fed to the phase detector.

The phase detector responds to phase variations. This is fed to the video canceller to suppress the fixed targets and provide the video output for moving targets. The block diagram of the MTI units integrated with radar is given in Fig. 3.

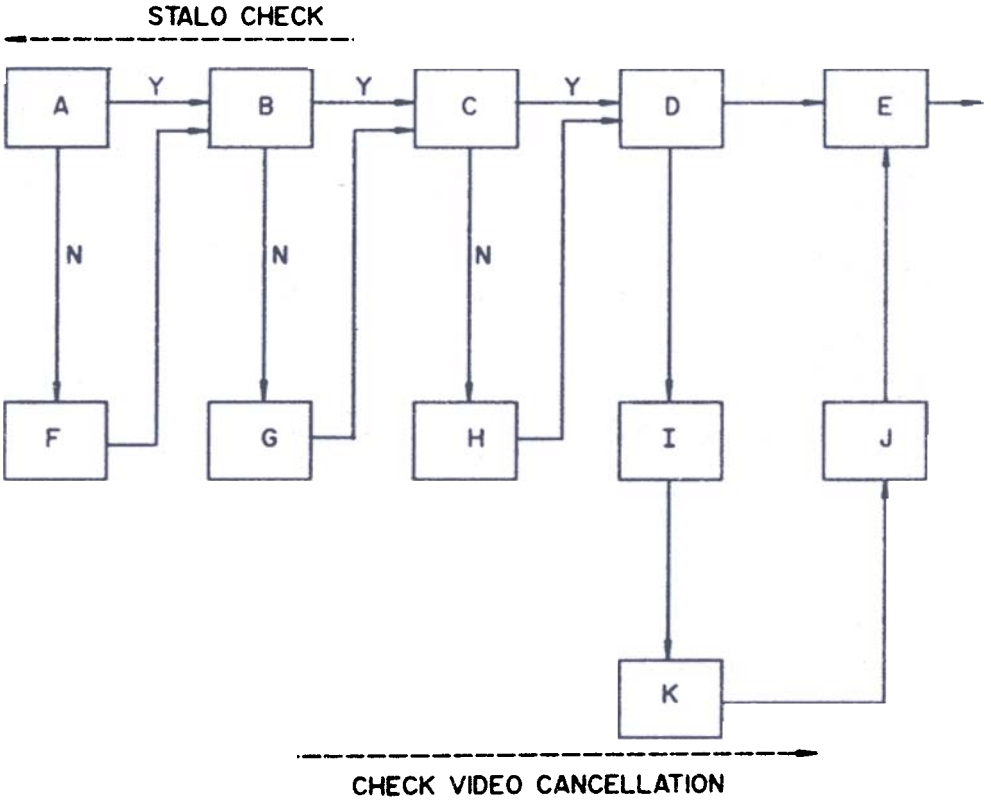
6.2 Adapting the Shell to the MTI Knowledge Base

To effect a saving in time while developing another diagnostic expert system, this system has been built around a shell. The entire system can be considered to be made of two parts; (a) the shell, and (b) the expert knowledge. The shell being the skeleton of the system, handles the user interface and the control mechanism. So for every new application, the shell can be retained and only the expertise added on. Thus it required only a week to build the system for the diagnosis of the MTI as opposed to a few months to build from the beginning.

In order to adapt the shell to a new domain, the experts' knowledge should be fitted into the knowledge base. This expertise has to be entered in a predefined format and put into the required slots. The allocated slots are : (a) the complaint dictionary, (b) the rules, and (c) the database.

The complaint dictionary is used by the shell to detect the validity of the keyed in complaint. In case of the MTI, the key words of the probable complaints and their respective codes are entered as an association list. In addition a list of permissible code patterns are given in another list. Entry is made using the standard editor 'Edlin'. They are entered in the same format as given in section 3. This is illustrated with an excerpt for the complaint – 'MTI not working'.

```
(SETQ R1 ' (
(MTI 1) (MOVING TARGET INDICATOR 1) (MOVING 1)
(TARGET 2)
('NDICATOR 3)
(FAULTY 8) (NOT 8) (FAULT 8) (FAILURE 8) (BAD 8) (PROBLEM 8)
(FUNCTIONING 9) (WORKING 9) (THROUGH 9) (THRO' 9))))
(SETQ R2' (
(1 8) (1 8 9) (1 2 3 8) (1 2 3 9)))
```



A: Switch 'ON' the radar and put in KLYS mode by means of switch 29S14. Check the radar parameters against the specification.

B: Set switch 29S14 to STALO and after 30 minutes stabilisation time, observe whether the crystal current reading are within the band marked for all the STALO frequencies selectable by means of 29S15. This can be done with 29S5 either in STANDBY or FILL.

C: Set switch 29S5 to OPERATION and observe the noise (grass) on the A/R scope. It should be the same as in the KLYS mode.

D: Set switch 29S14 and 29S15 to VIDEO CANCELLATION FTC OFF, gain control and RI to NORMAL setting. Bring the variable range marker to minimum position. Now with & S4 at EXT are pulses appearing on A/R scope?

E: BLOCK1

F: Do the fault finding as per radar manual and bring the equipment within specification

G: Take the normal precautions and open unit 2a, 2b covers. Adjust the STALO attenuator WR4D in unit 2a so that the crystal current is within the band for all STALO frequencies. If there is no indication of the crystal current then test as per chart number 1.

H: Check AGC-DC voltage at the relevant test points. If not present, carry out fault analysis as per radar manual and rectify fault. If the AGC voltage is within limits, replace the STALO with a serviceable one and check,

Observe the trigger wavefrom at 2 kb trigger test points.

J: BLOCK2

K: Continue fault finding as per chart number 2.

Figure 3. Part of the fault finding chart for MTI of the radar.

A part of the fault finding chart for the MTI is given in Fig. 4. The heuristic information regarding the more obvious symptoms of a fault, indicators to confirm or rule out a fault, the more probable/important failures have been incorporated in the figure This is entered as rules in the format as shown in Appendix E. Information for the help and explanation facility are entered in LISP format as associated lists in the database, as shown in Appendix F.

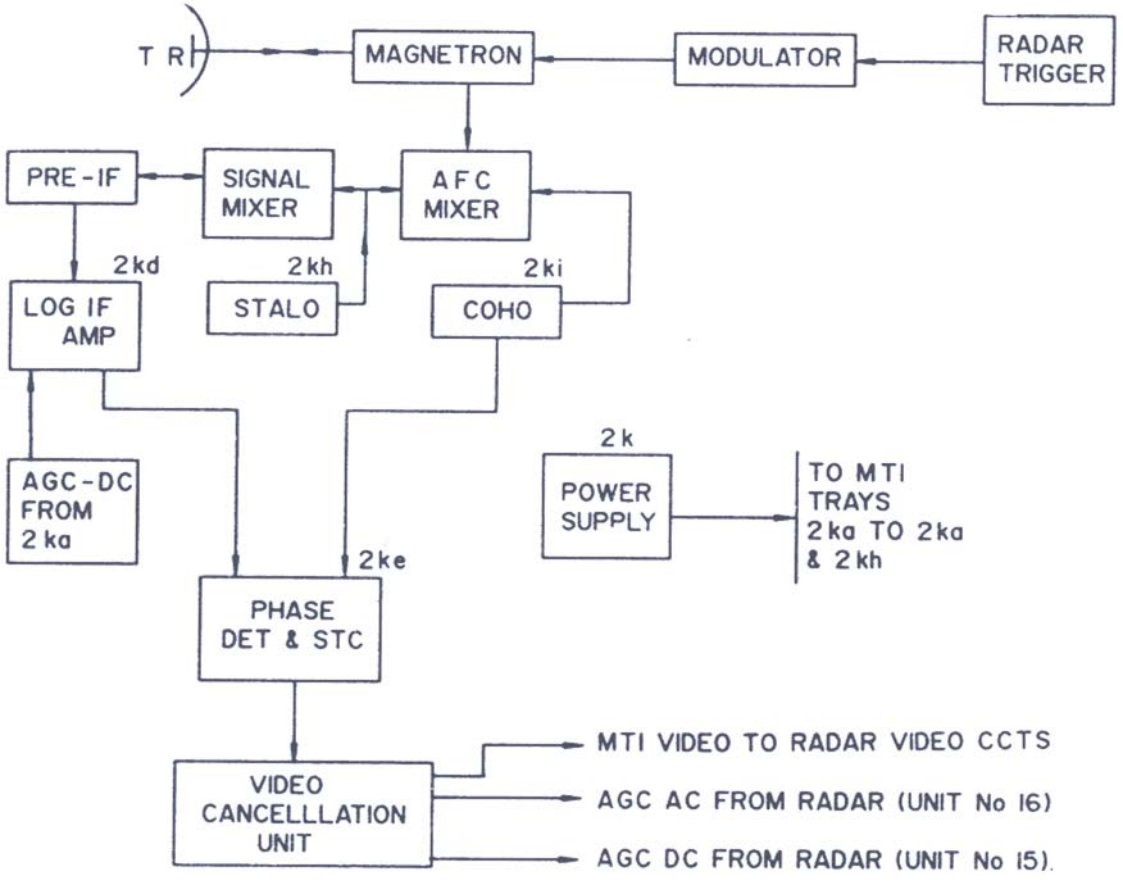


Figure 4. Block diagram of the unit integrated with radar.

Understanding rules and maintaining the database and dictionary in common English, is far too difficult, especially in domains where the vocabulary has not been identified and organised for the program's use. So to bridge the gap between LISP and free-of-form English text, an intermediate form has been accepted. A sample consultation of the MTI system from the keyed in complaint to the explanation, alongwith the other shell facilities have been shown in Appendix G.

7. IMPLEMENTATION DETAILS

Initially this system was built in BASIC and run on an Uptron 800 machine. This had many glaring and apparent shortcomings. So the next version was implemented in LISP and it helped to overcome the above drawbacks.

The key to many of the problems encountered in the first instance was list processing and symbol manipulation. In LISP, elementary objects are called atoms, and atoms form lists Together they permit symbol manipulation. The IF-THEN rules

in Appendix E, are an example of these. This enabled a convenient way of representing knowledge manipulation symbols in LISP, and also facilitated the development of a convenient English-like user interface.

Besides, LISP being a highly interactive language, the development process was made simpler. Another convenience found was the ease with which programs could be modified and extended. A phenomenal feature about LISP is that both program and data have the same format. So one LISP program can create and even modify another.

This version of the system has been coded in UNXLISP. Approximately a thousand lines of code need to be interpreted by the UNXLISP interpreter. The explanation facility in addition to repeating the trace, picks out from the database the explanation corresponding to the rule number and reads it out.

The explanation program is also a helpful debugging aid for the system developer. Without having to resort to LISP level manipulations, he can examine any interfaces that were made, find out why others failed and thereby correct errors or omissions in the knowledge base. The explanation facility has been elaborated in Appendix H. It runs under the MS-DOS operating system on a PC compatible. A consulation run takes approximately 10 minutes.

8. LIMITATIONS

Expert system technology is expanding its limits. Many of the problems with the classical rule-based approach become apparent as larger and more complex domains are tried. And therefore, a substantial progress in techniques and methodology are required.

Expert systems are typically based on heuristics in the form of rules. This simple approach allows a modular representation in the form of rules and a simple inference as some form of rule chaining. These have no access to the underlying reasoning which validates the rules and hence the explanation facilities cannot justify actions in their entirity. Heuristics may fail occasionally and the system will not be suitable for crucial applications. Above all, these systems cannot exhibit learning capabilities and hence periodical modifications will have to be made to improve the expertise of the system. 'Deep knowledge' (as opposed to 'shallow knowledge') is found to be the solution to these problems. Deep knowledge is the entirity of the knowledge (including common-sense knowledge), that the expert has in that domain. This mandates the need for more structured knowledge acquisition techniques and a richer knowledge representation structure. Systems employing deep knowledge pave the way for the second generation of expert systems.

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APPENDIX A

ENTER ONE COMPLAINT AT A TIME
ENTER COMPLAINT WITHIN BRACKETS
AGAINST THE QUESTION MARK TYPE
FURTHER HELP REQD.....TYPE H
FOR WHY A QUERY IS ASKED.....TYPE W
TO GO BACK.....TYPE B
IF ANS. TO QUERY IS YES.....TYPE Y
IF ANS. TO QUERY IS NO.....TYPE N
HELP REQD. TO KEY IN COMPLAINT?.....TYPE Y/N n
YOUR COMPLAINT? (CROSS TALK NOT ABSENT)
COMPLAINT INVALID
HELP REQD TO KEY IN COMPLAINT?.....TYPE Y/N y
PROBABLE COMPLAINTS :
1) NO DIAL TONE 2) NO RINGBACK TONE 3) NO RINGING 4) NOISE ON LINE 5) WRONG NUMBER 6) CROSS TALK 7) CALL NOT THRO. 8) CALL GETS CUT-OFF WHILE SPEAKING 9) CONNECTION MADE DOES NOT GET DISCONNECTED AFTER END OF CALL 10) PHONE RINGING CONTINUOUSLY 11) NUMBER UNOBTAINABLE—TONE OBTAINED ALWAYS 12) PRIORITY—WARNING TONE NOT HEARD 13) PHONE PERMANENTLY BUSY
TO CONTINUE.....TYPE C
TO EXIT.....TYPE E
YOUR COMPLAINT? (I GET A WRONG NUMBER)
(8 & 13) YOUR COMPLAINT IS VALID. CARRYING ON? y
(TEST & FIND:—RINGING & RINGBACK TONE HEARD BUT CALL GOES TO WRONG NUMBER)? n
(* KEY IN YOUR COMPLAINT AGAIN AS – CALL NOT THROUGH*)

THERE ARE TWO EXPLANATION FACILITIES :

(1) A TRACE OF THE PATH OF REASONING

(2) AN EXPLANATION AND CONFIRMATION

WANT A TRACE? Y/N n

WANT AN EXPLANATION? Y/N n

TO CONTINUE..... .TYPE C

TO EXIT..... .TYPE E

? e

BYE

/USR/LOGIN–> !

APPENDIX B

TESTABILITY RULES

RULE1 : IF [(MAINS A/C INPUT VTG WITHIN THE RANGE 180 TO 260 VTS) AND
(MAINS A/C INPUT CURRENT WITHIN THE RANGE 7 TO 12 AMPS) AND
(MAINS A/C INPUT RIPPLE WITHIN THE RANGE 48 TO 52 HZ)]

THEN (MAINS A/C SUPPLY OKAY. LOGIC SUPPLIES ARE TESTABLE)

ELSE (MAINS NOT OKAY) AND GOTO RULE 2

RULE2 IF [(BATTERY VOLTAGE WITHIN THE RANGE 42 TO 52 VTS) AND
(BATTERY CURRENT WITHIN THE RANGE 20 TO 40 AMPS)]

THEN (BATTERY OKAY. LOGIC SUPPLIES NOT TESTABLE)

ELSE (BATTERY NOT OKAY. LOGIC SUPPLIES NOT TESTABLE. MAKE MAINS/BATTERY OKAY BEFORE PROCEEDING)

STRATEGY RULES

RULE3 IF (NOISE EXISTS ON LINE)

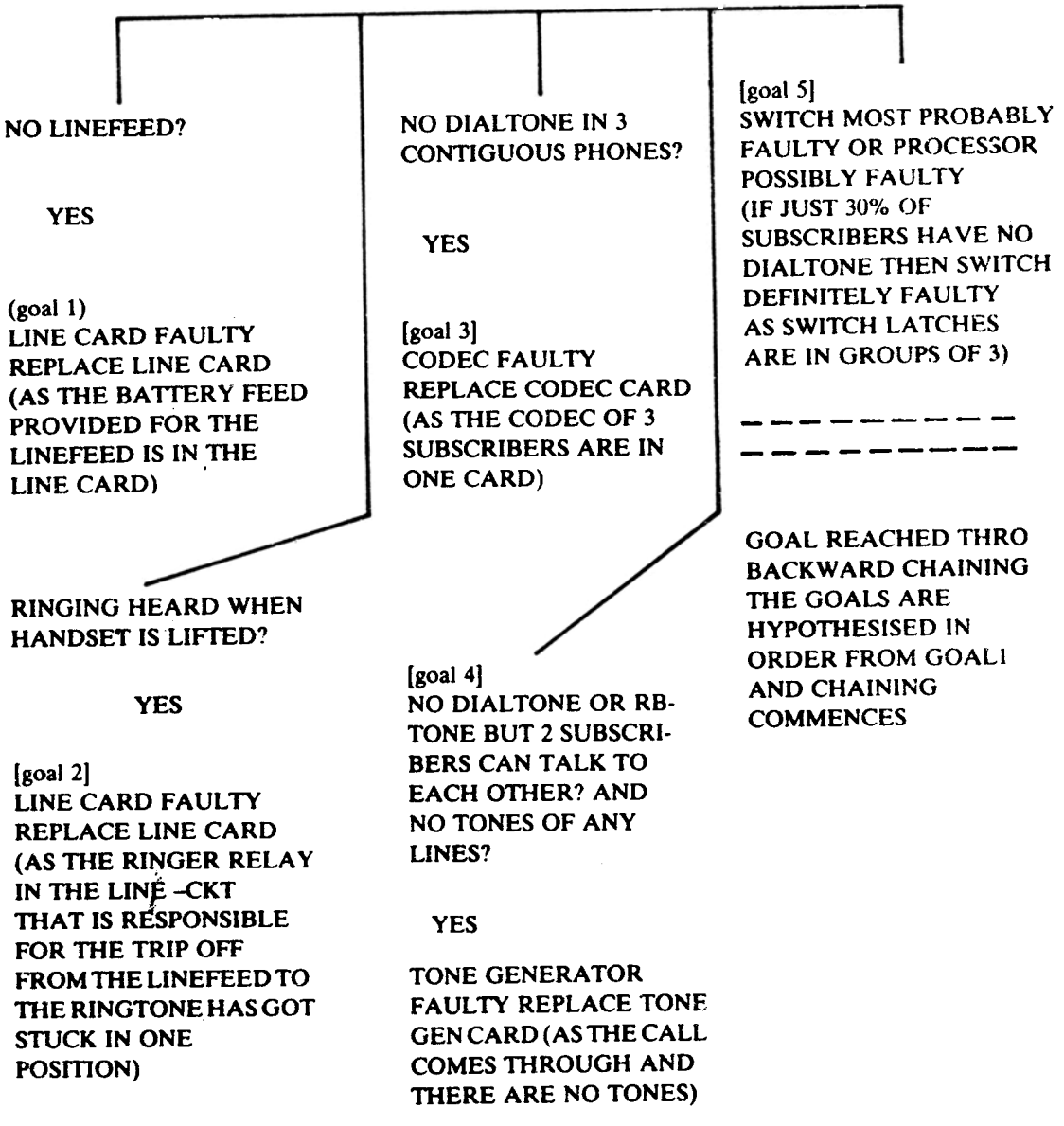
THEN (CHECK IF NOISY CONDITION EXISTS ON ONE PHONE ONLY)

RULE4 IF (NOISY CONDITION XISTS ON ONE PHONE ONLY)

THEN (CODEC CARD PROBABLY FAULTY
ELSE (FAULT PROBABLY LIES IN SWITCH OR PROCESSOR)

APPENDIX C

BACKWARD CHAINING FROM THE NO DIALTONE COMPLAINT



(REPLACING OF CARD IS CONFIRMED AFTER CHAINING FORWARDS ALONG A DIFFERENT PATH)

CHAINING FORWARDS FROM THE NOISE AND WRONG NUMBER COMPLAINT
(PART OF THE FLOW-CHART FOR THE NOISE COMPLAINT)

NOISE ON LINE

YES

NOISE ON ONE PHONE ONLY?

CODEC CARD FAULTY
REPLACE CODEC CARD
(BECAUSE OF AGEING
OR COMPONENT
FAILURE OF CODEC)

SWITCH CARD FAULTY

(CONNECTION MADE TO
WRONG POINTS BY
SWITCH OR ONE WAY
CONNECTION)

(PART OF THE FLOW CHART FOR THE WRONG NUMBER COMPLAINT)

WRONG NUMBER

YES

CHECK IF RINGING AND RBT
ARE HEARD BUT CALL GOES
TO WRONG NUMBER

SWITCH CARD FAULTY
REPLACE SWITCH CARD

FAULT PERSISTS?

HALT

PROCESSOR CARD FAULTY
(AT THE I/O PORTS)
CONFIRMED IF ----------

APPENDIX D

A SAMPLE CONSULTATION

ENTER ONE COMPLAINT AT A TIME

ENTER COMPLAINT WITHIN BRACKETS

AGAINST THE QUESTION MARK TYPE

FURTHER HELP REQD..... .TYPE H

FOR WHY A QUERY IS ASKED..... .TYPE W

TO GO BACK..... .TYPE B

IF ANS. TO QUERY IS YES..... ..TYPE Y

IF ANS. TO QUERY IS NO..... .TYPE N

HELP REQD. TO KEY IN COMPLAINT?.....TYPE Y/N y

PROBABLE COMPLAINTS :

1) NO DIALTONE 2) NO RINGBACK TONE 3) NO RINGING 4) NOISE ON LINE 5) WRONG NUMBER 6) CROSS TALK 7) CALL NOT THRO. 8) CALL GETS CUT-OFF WHILE SPEAKING 9) CONNECTION DOES NOT GET DISCONNECTED AFTER THE CALL 10) PHONE RINGING CONTINUOUSLY 11) PHONE PERMANENTLY BUSY 12) NUMBER UNOBTAINABLE—TONE OBTAINED ALWAYS

YOUR COMPLAINT? (NO DIALTONE IS HEARD)

YOUR COMPLAINT IS VALID. CARRYING ON? y

(TEST & FIND : —RINGING HEARD WHEN HANDSET IS LIFTED? n

(TEST & FIND : —LINEFEED)? y

(TEST & FIND : —DIALTONE PRESENT IN 3 CONTIGUOUS PHONES)? n

(TEST & FIND : —IF 2 SUBSCRIBERS CAN TALK TO EACH OTHER)? n

(*FAULT PROBABLY WITH SWITCH CARD OR PROCESSOR CARD*)

THERE ARE TWO EXPLANATION FACILITIES :

1) A TRACE OF THE PATH OF REASONING

2) AN EXPLANATION AND CONFIRMATION

WANT A TRACE? Y/N n

WANT AN EXPLANATION? Y/N y

6. LOOK FOR THE FOLL. TO CONFIRM THIS FAULT :

1) AS BOTH TONES AND SPEECH DO NOT COME THRO. THE FAULT IS MOST PROBABLY WITH THE SWITCH CARD. OTHER SYMPTOMS ARE–NOISE ON LINE AND WRONG NUMBER

IF ON CHANGING THE SWITCH CARD AND THE FAULT PERSISTS THE FAULT IS WITH THE PROCESSOR CARD – SOFTWARE OR HARDWARE REPLACE PROCESSOR CARD

AS THE LINE CARD, CODEC CARD AND TONE GENERATOR CARD HAVE BEEN RULED OUT

(*FAULT PROBABLY WITH SWITCH CARD OR PROCESSOR CARD*) WAS OBSERVED SINCE (IF 2 SUBSCRIBERS CAN TALK TO EACH OTHER) GAVE A NEGATIVE RESPONSE

5. (IF 2 SUBSCRIBERS CAN TALK TO EACH OTHER) WAS OBSERVED SINCE (DIALTONE PRESENT IN 3 CONTIGUOUS PHONES (GAVE A NEGATIVE RESPONSE

4. (DIALTONE PRESENT IN 3 CONTIGUOUS PHONES) WAS OBSERVED SINCE (LINEFEED) GAVE A POSITIVE RESPONSE

2. (LINEFEED) WAS OBSERVED
SINCE (RINGING HEARD WHEN HANDSET IS LIFTED) GAVE A NEGATIVE RESPONSE

3. (RINGING HEARD WHEN HANDSET IS LIFTED) WAS OBSERVED SINCE (NO DIALTONE) GAVE A POSITIVE RESPONSE

0. (NO DIALTONE) WAS OBSERVED SINCE IT WAS THE TYPED IN COMPLAINT

APPENDIX E

FORMAT FOR MTI RULES

(SETQ R'(

((1 A) (THEN B) (ELSE C))

((2 (TEST & FIND :- SWITCH ON THE RADAR & PUT IN KLYS MODE RADAR PARAMETERS MATCH WITH SPECIFICATIONS))

(THEN (TEST & FIND :--- SET SWITCH 29S14 TO STALO WAIT FOR 30 MINS. CRYSTAL CURRENT READING WITHIN THE BAND MARKED FOR STALO FREQS.))

(ELSE (* DO THE FAULT FINDING AS PER RADAR MANUAL AND BRING THE EQUIPMENT WITHIN SPECIFICATION *)))

– THE NUMBERS 1 & 2 ARE THE RULE NUMBERS

– THE * IN THE 'ELSE' IS USED TO INDICATE A GOAL CONDITION

APPENDIX – F

FORMAT FOR THE HELP FACILITY FOR THE ABOVE RULES IN THE DATABASE

(SETQ HELP NOW'(

(1 (PRINC 'THE FIRST RULE IS A DUMMY')

(2 (PRINC 'PUT RADAR IN KLYS MODE
BY MEANS OF SWITCH 29S14')

))

APPENDIX G

/USR/LOGIN->(FINAL.1)

THE QUESTIONS ASKED ARE TO BE ANSWERED :

QUESTIONS SELECT THE STRATEGY FOR FAULT DIAGNOSIS

CHARTS DETERMINE THE TESTABILITY OF A SYSTEM

ENTER ONE COMPLAINT AT A TIME

ENTER COMPLAINT WITHIN BRACKETS

AGAINST THE QUESTION MARK TYPE

FURTHER HELP REQD..... ...TYPE H

FOR WHY A QUERY IS ASKED..... ...TYPE W

TO GO BACK..... ...TYPE B

IF ANS. TO QUERY IS YES..... ....TYPE Y

IF ANS. TO QUERY IS NO..... ....TYPE N

HELP REQD. TO KEY IN COMPLAINT?.....TYPE Y/N n

YOUR COMPLAINT? (SYSTEM NOT WORKING)

(3 & 2 YOUR COMPLAINT IS VALID. CARRYING ON? y

TEST & FIND :--- SWITCH ON THE RADAR & PUT IN KLYS MODE RADAR PARAMETERS MATCH WITH SPECIFICATIONS)? y

(TEST & FIND :--- SET SWITCH 29S14 TO STALO WAIT FOR 30 MINS

CRYSTAL CURRENT READING WITHIN BAND MARKED FOR STALO FREQ)? h

SET THE SWITCH AND WAIT FOR 30 MINS. FOR STABILISATION THE CRYSTAL CURRENT FREQS. WITHIN THE BAND MARKED FOR STALO FREQS. ARE SELECTABLE BY MEANS OF 29S15. THIS CAN BE DONE WITH 29S5 EITHER IN STANDBY OR FILL? n

(TEST & FIND :--- ADJUST STALO ATTENUATOR WR 40 IN UNIT 2 A CRYSTAL CURRENT WITHIN RANGE)? w

TO TRIGGER THE FOLL. RULE :

IF (TEST & FIND :--- ADJUST STALO ATTENUATOR WR 40 IN UNIT 2 A CRYSTAL CURRENT WITHIN RANGE)

THEN (TEST & FIND :--- SET SWITCH 29S5 TO OPERATION. NOISE ON A-R SCOPE SAME AS IN KLYS MODE

ELSE (TEST AS PER CHART NUMBER A)

(TEST & FIND :--- ADJUST STALO ATTENUATOR WR 40 IN UNIT 2 A CRYSTAL CURRENT WITHIN RANGE)? h

TAKE NORMAL PRECAUTIONS AND OPEN UNIT 2 A & 2 B COVERS CRYSTAL CURRENT SHOULD BE CHECKED IN THE BAND OF ALL STALO FREQS.

-? y

(TEST & FIND :— SET SWITCH 29S5 TO OPERATION. NOISE ON A-R SCOPE SAME AS IN KLYS MODE)? n

(TEST & FIND :— AGC-DC VOLTAGES AT RELEVANT TEST POINTS WITHIN RANGE)? b

TO GO BACK TO PREVIOUS QUESTION .....TYPE 1

TO GO BACK TO ANY OTHER QUESTION.....TYPE 2

(TEST & FIND :— SET SWITCH 29S5 TO OPERATION. NOISE ON A-R SCOPE SAME AS IN KLYS MODE)? n

(TEST & FIND :— AGC-DC VOLTAGES AT RELEVANT TEST POINTS WITHIN RANGE)? n

(CARRY OUT FAULT ANALYSIS AS PER RADAR MANUAL & RECTIFY FAULT)

* THERE ARE TWO EXPLANATION FACILITIES :

(1) A TRACE OF THE PATH OF REASONING

(2) AN EXPLANATION AND CONFIRMATION

WANT A TRACE? Y/N n

WANT AN EXPLANATION? Y/N n

TO CONTINUE.....TYPE C

TO EXIT.....TYPE E

BYE

/USR/LOGIN–>

APPENDIX H

ENTER ONE COMPLAINT AT A TIME

ENTER COMPLAINT WITHIN BRACKETS

AGAINST THE QUESTION MARK TYPE

FURTHER HELP REQD..... ..... TYPE H

. FOR WHY A QUERY IS ASKED..... .....TYPE W

TO GO BACK..... .....TYPE B

IF ANS. TO QUERY IS YES..... .....TYPE Y

IF ANS. TO QUERY IS NO..... .....TYPE N

HELP REQD. TO KEY IN COMPLAINT?.....TYPE Y/N n

YOUR COMPLAINT? (CALL NOT GOING THRO.)

(9 & 6) YOUR COMPLAINT IS VALID. CARRYING ON? y

(TEST & FIND :— ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING)? h

FAULT PERSISTS EVEN WITH OTHER PHONES? w

TO TRIGGER THE FOLL. RULES :

IF (TEST & FIND :— ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING)

THEN (* SWITCH PROBABLY FAULT*)

ELSE (TEST & FIND :— LET YOUR PHONE BE = X AND THE OTHER PHONE BE = Y : DOES X HEAR Y)

(TEST & FIND :— ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING)? n

(TEST & FIND :— LET YOUR PHONE BE = X AND THE OTHER PHONE BE = Y : DOES X HEAR Y)? y

INVALID ENTRY - TAKE HELP

ENTER ONE COMPLAINT AT A TIME

ENTER COMPLAINT WITHIN BRACKETS

AGAINST THE QUESTION MARK TYPE

FURTHER HELP REQD.....TYPE H

FOR WHY A QUERY IS ASKED.....TYPE W

TO GO BACK.....TYPE B

IF ANS. TO QUERY IS YES.....TYPE Y

IF ANS. TO QUERY IS NO.....TYPE N

(TEST & FIND :— MAKE A CALL FROM X TO ANOTHER PHONE SAY Z : CALL COMES THRO FROM X TO Z)? b

TO GO BACK TO PREVIOUS QUESTION.....TYPE 1

TO GO BACK TO ANY OTHER QUESTION.....TYPE 2

TO RECOLLECT THE QUESTION NUMBER TO GO BACK TO - TAKE A TRACE

WANT A TRACE? Y/N n

25. (MAKE A CALL FROM X TO ANOTHER PHONE SAY Z : CALL COMES THRO FROM X TO Z) WAS OBSERVED SINCE (LET YOUR PHONE BE = X AND THE OTHER PHONE BE = Y : DOES X HEAR Y) GAVE A POSITIVE RESPONSE

24. (LET YOUR PHONE BE = X AND THE OTHER PHONE BE = Y : DOES X HEAR Y) WAS OBSERVED

SINCE (ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING) GAVE A NEGATIVE RESPONSE

23. (ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING) WAS OBSERVED

SINCE (CALL NO THROUGH) GAVE A POSITIVE RESPONSE

0. (CALL NOT THROUGH) WAS OBSERVED

SINCE IT WAS THE TYPED IN COMPLAINT

THAT IS THE TRACE

WHICH QUESTION TO GO BACK TO ? 24

(TEST & FIND :--- LET YOUR PHONE BE = X AND THE OTHER PHONE BE = Y : DOES X HEAR Y)? n

(TEST & FIND :--- MAKE A CALL FROM X TO ANOTHER PHONE SAY Z : X HEARS Z)? y

(*REPLACE CODEC OF Y*)

*THERE ARE TWO EXPLANATION FACILITIES :

(1) A TRACE OF THE PATH OF REASONING

(2) AN EXPLANATION AND CONFIRMATION

WANT A TRACE? Y/N y

WANT AN EXPLANATION? Y/N y

28. AS X HEARS Z, CODER OF Y IS FAULTY

(*REPLACE CODEC OF Y*) WAS OBSERVED

SINCE (MAKE A CALL FROM X TO ANOTHER PHONE SAY Z : X HEARS Z) GAVE A POSITIVE RESPONSE

25. AS X DOES NOT HEAR Y & Y MAY OR MAY NOT HEAR X

(MAKE A CALL FROM X TO ANOTHER PHONE SAY Z : X HEARS Z) WAS OBSERVED

SINCE (LET YOUR PHONE BE = X AND THE OTHER PHONE = Y : DOES X HEAR Y) GAVE A NEGATIVE RESPONSE

24. (LET YOUR PHONE BE = X AND THE OTHER PHONE = Y : DOES X HEAR Y) WAS OBSERVED

SINCE (ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING) GAVE A NEGATIVE RESPONSE

23. (ON CALLING ANOTHER 2 PHONES : CALLED SUBSCRIBERS NOT HEARD OR NOISY CONDITION PERSISTING) WAS OBSERVED

SINCE (CALL NOT THROUGH) GAVE A POSITIVE RESPONSE

0. (CALL NOT THROUGH) WAS OBSERVED

SINCE IT WAS THE TYPED IN COMPLAINT

THAT IS THE EXPLANATION

TO CONTINUE.....TYPE C

TO EXIT.....TYPE E

BYE