Telecommunications networks for remote electricity supply metering and load control

Thesis

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7.1 Introduction

In the early part of 1993 a series of experiments was commissioned in the United Kingdom to evaluate the suitability of three different types of communication system for the purpose of utility load management. These were:

(a) CALMS (Credit And Loan Management System) developed by SEEBOARD (South Eastern Electricity Board) which utilised the local telephone circuit idle line facility.

(b) RADIO TELESWITCHING which utilised a special LF radio frequency receiver to decode digital signals superimposed on the radio frequency carrier of a national broadcast station. The system provides uni-directional communication with the consumer.

(c) MAINSBORNE TELECONTROL developed by Thorn EMI which utilised spread spectrum signalling along power lines in the 50kHz to 150kHz band providing bi-directional communication with the consumer.

7.2 CALMS was a system built around an 'intelligent' terminal in the consumers home in two-way communication with the Electricity Board.
There were two particular aspects which combined to form the overall system:

1. A microelectronic unit (CALMU) which was located on the customer's premises and is illustrated in Fig. (7.1) and replaced the existing meter(s) and tariff time switch.

2. A communication system providing real-time two-way communication between the CALMUs and the Electricity Board's accounting, engineering control networks.

**System Facilities**

The system, when full established aimed to provide the following:

1. Measurement and recording of demand and maximum demand.

2. Remotely-selectable tariff arrangements from a menu of pre-programmed options.

3. Calculation of outstanding charges for display to the consumer.

4. Provision of electrical loading and demand information to assist network planning.

5. To provide tariff and price revisions remotely at a given date and time.
6. Remote reading of a 3-rate meter.

7. Accept customer payments remotely via the CALMU.

8. Present a range of information to the customer via a touch panel and display on the CALMU.

9. Provide enhanced types of tariff and switching of selected consumer appliance.

10. Apply load limits for use in tariffs or in system emergencies providing an alternative to rota disconnections.

11. Allow metering and accounting for gas and water utilities similar to those for electricity using inputs from metering sensors.

12. Earth leakage protection facilities at the consumer's premises.

7.2.1 The hardware at the consumer's premises comprised of two enclosures. The 'mains interface' unit situated at the supply intake position and the 'touch panel' unit situated conveniently for the consumer as detailed in Fig (7.1).

The design criteria was to minimise hardware, reduce cost and maximise system reliability. Accordingly, all possible functions were carried out in the software of the microcomputer.
The major electronic components of the CALMU were a pair of Intel 8022 single-chip microprocessors running at a nominal clock rate of 4.6mHz but locked to the mains frequency by means of a software-controlled phase-locked loop. Non-volatile data storage was accomplished by utilising a CMOS RAM with super-capacitor back-up. A section of the memory had to be inviolable by communication such that vital information such as meter readings and identification number could not be corrupted in any way.

Energy measurement was accomplished using the on-board analogue-to-digital-convertor (ADC) contained within one of the 8022s (i.e. the A processor) to sample low voltage samples of the mains voltage and current obtained via metering transducers. Production from the 8-bit ADC was claimed to be better than 2% over the range of 1 to 100 amperes expected on each metered circuit. At regular intervals, the accumulated sample totals for voltage and in-phase current were transferred to the non-volatile memory under the control of the second 8022 (the B processor) and the majority of calculations were then carried out on this date by the same processor referring to parameters stored in ROM and non-volatile RAM.

For effective load management it was decided that three separate switchable customer circuits were desirable and triac solid state switching was employed.

The prototype consumer touch panel unit was based on a third 8022 microprocessor and communicated with the main B processor in serial form via a signal cable. In addition to customer-activated displays of such information as meter readings, time and account date displays were also incorporated to give warnings of abnormal occurrences affecting supply, for example earth faults.
A capacitive type touch panel was preferred to a push button type for the consumer input for reasons of both economy and reliability. A fluorescent indicator panel (FIP) was chosen for clarity and long life.

7.2.2 Communications. The philosophy in the design of the CALMU was that as far as possible it should be independent of the choice of communication medium. The scheme prototype utilised the existing telephone lines on a basis known as 'Idle-Line Working' (ILW). This could be supplemented by the use of one-way signalling via radio broadcasting using techniques developed jointly by the Central Electricity Generating Board (CEGB) and the British Broadcasting Corporation (BBC) (i.e by phase modulation of the 200kHz carrier of the BBC Radio 4 broadcast transmitter).

The system called for communication over the telephone lines to consumers to be controlled by data concentrators situated in telephone exchanges. In order to permit expansion of memory or capabilities the data concentrator hardware was designed on a modular basis using Intel single-board computer (ISBC) components, of which the 8086 microprocessor formed the heart.

Each data concentrator was designed to act as a message reading device as well as maintaining a routine scan of its 'family' of 10,000 CALMUs interrogating each for a list of status flags. This routine was designed to be completed at intervals of approximately one hour, depending upon the level of other CALMU traffic which takes priority. The data rate over the links was designed to be 300 bits/second utilising message protocols specifically designed for efficient and secure communication with the CALMUs. A CRC (cyclic redundancy code) error checking method was incorporated and any invalid message was rejected by the CALMU. Failure to evoke a response would prompt a re-try or fault report.
Ultimately it was proposed that the data concentrators would integrate with the overall Board communications system as illustrated in Fig. (7.2) and for the duration of the field trials two dedicated links were utilised. The first was used to connect to data concentrator in the telephone exchange with the NAS 9000 m.inframe computer at SEEBOARD's Central Accounts Office in Worthing. The other was used to connect the data concentrator with the PDP 11/34 computer in the engineering control centre at Dorking, both links operated in full duplex mode at 9.6 kbits/s and in the case of the NAS 9000, a protocol converter was introduced to translate messages into the format necessary for the IBM 3705 controller. Priority queuing of transactions was also provided for commands such as water-heating control for load management purposes (high priority) to be actuated before a previously queued transaction such as meter reading (low priority).

7.3
Radio Teleswitching

7.3.1
The Radio Transmission

These trials were made possible by developments in broadcasting techniques made by the BBC (British Broadcasting Corporation). The BBC is concealing additional information in some of its sound broadcasts just as Teletext is concealed in television broadcasts. This information includes channel and programme identification, time and date and signals for other purposes.

These time and date signals were utilised in a radio timeswitch which, it was considered, might replace existing electromechanical timeswitches, and a small portion of the remaining data capacity was used for remote load switching by the ESI. The data was coded on to a normal BBC broadcast transmission - Radio 4 on (then 200kHz) long wave.
Of the BBC domestic transmissions only the 200kHz Droitwich transmitter, broadcasting Radio 4 with a radiated power of 400kW is able to cover the whole of England and Wales. Scotland is covered by two other 200kHz transmitters which are phase synchronised to Droitwich. The signal strength is such that there should be little difficulty in receiving the transmissions except perhaps in parts of Cornwall and along Hadrian's Wall.

The 200kHz carrier was phase modulated by plus or minus 110° either side of its nominal position to indicate a binary '1' or '0' (see Fig (7.3)). The data rate was 50 bits/sec. However, the 200kHz broadcast from Droitwich was an international frequency standard and therefore should not be permanently phase shifted. To avoid these phase shifts the data was secondary coded to ensure that there were as many '1's as '0's.

For the initial trials the data was sent in 100 bit frames each taking two seconds to broadcast as illustrated in Fig. (7.4). Each frame starts with a frame alignment word (FAW) so that the receiver/decoder can lock on to the data, followed by six words of information and a CRC (cyclic redundancy code) check word. Two of the six information words were used during the trials to send previously specified codes that would be recognised by the trial receiver/decoders.

Throughout the course of the trials, data transmissions by this method took place during the early hours of the morning from 0100 to 0530 and, during some of this time, World Service programmes were also broadcast.

After extensive testing it was concluded that the phase modulated, slow speed data, did not interfere with reception of the broadcast material and did not upset the use of Radio 4 as a then frequency standard on 200kHz.
CARRIER PHASE SHIFTED FOR DIGITAL DATA

Fig 7.3

CARRIER PHASE LEADS BY $11 \frac{1}{4}^\circ$

CARRIER PHASE LAGS BY $11 \frac{1}{4}^\circ$

<table>
<thead>
<tr>
<th>FRAME ALIGNMENT WORD (FAW)</th>
<th>ESI OR BBC TEST CODES (2 WORDS)</th>
<th>BBC INFORMATION (4 WORDS)</th>
<th>CRC CHECK WORD</th>
</tr>
</thead>
</table>

1 FRAME OF 100 BITS TAKING 2 SECONDS TO BROADCAST

100 BIT FRAME

Fig 7.4
7.3.2
Trial Receiver/Decoder

The trial receiver/decoder was designed to test out the method of transmission from Droitwich to consumers' premises. To achieve this a radio receiver was required which was capable of detecting the low level of phase modulation and converting it to a binary sequence for decoding by a microprocessor. Two techniques were employed for detecting the phase modulation, (1) a conventional frequency discriminator followed by an integrator or (2) a phase locked loop. Fig. (7.5) illustrates, in block diagram form, a typical early trial receiver/decoder.

The data stream is examined by the microprocessor to find the frame alignment word. The following six words of information are stored and checked using the CRC check word. If they are correct the first two words (making one test code) are compared with the three codes which have previously been specified and, if they match, one of the three counters is incremented. The trial receiver/decoder was able to display the number of each code received and may be read each day. A fourth counter displayed the number of times the CRC check word indicated faulty receipt of the data. On power failure, the counters reset to zero and the display flashed until reset. There was also an indication that the broadcast was being received satisfactorily. Fig (7.6) shows a prototype unit as installed in a consumer's premises.

7.3.3
The Trials

The trials were initially conducted by the Electricity Council and CEGB Market Research Branch. Each Area Board was supplied with 10 receivers from each of two manufacturers. At the end of a three month period the 120 trial sites were tested by each Board and the information collated and passed back
Fig 7.5  Block Diagram Trial Rx/Decoder

Fig 7.6  Radio Teleswitch
to the Electricity Council. The main information here being the number of
code counts and CRC failures logged over the test period.

7.4
Mainsborne Telecontrol

This trial system was developed by Thorn EMI and consisted essentially of
three principal components interconnected as shown in Fig (7.7).

1. A 'Central Controller' situated in the local transformer chamber which
   was linked by telephone line to the overall load management control
   system and is shown in Fig. (7.8).

2. A 'Home Unit' fitted at the consumer's electricity meter position which
   linked with the electricity, gas and, if required, water supplies as
   illustrated in Fig. (7.9). Specially designed consumption meters are
   used which emit pulses each time a predetermined quantity of
   electricity, gas or water has been consumed.

3. A 'Customer Display' unit fitted at a convenient location inside the
   consumers premises as illustrated in Fig. (7.10).

7.4.1
Customer Controller

The Central Controller could communicate via the mains (spread spectrum
techniques) with up to 1024 addresses using individual, groups or master
codes and also conveyed data to and received data from Load Management
Control over a telephone line. It contained a clock/calendar facility
permitting real time instructions to be sent to the Home Units.
CONSUMER INSTALLATION

SITE 1

TRANSFORMER CHAMBER

CENTRAL CONTROLLER

LOW VOLTAGE ELECTRICITY MAINS

DATEL LINK TO EACH SITE

ELECTRICITY OPERATIONS ROOM
GAS OPERATIONS ROOM
WATER OPERATIONS ROOM

FIGURE 7.7

SCHEMATIC MAINSBORNE TELECONTROL
A Customer Display Unit

Fig 7.10
Communication with the Home Units was at a rate of 200 baud and there was a communication module on each phase of the mains distribution system. Normally the central controller called the Home Units at preset times to read meters and, if required, cleared meter reading buffers of statistical data.

Any Home Unit activity in relation to communication caused an alert or interrupt message requesting service. Meter readings were passed back to the Load Management Control at pre-determined intervals. The Central Controller also passed messages from Load Management Control onward to specific Home Units or groups of Home Units to effect a change in load.

There were 500 kbytes of non-volatile, bubble memory storage which was capable of storing 3 days of 48 half hourly meter readings from all three utilities as well as storing data awaiting retransmission upstream to Load Management Control or downstream to the Home Units.

7.4.2
The Home Unit

The Home Unit comprised a home module and a communications module. With dimensions of 250mm x 160mm x 144mm it was designed to fit into a conventional meter box along with other metering equipment.

It interfaced with pulsing electricity, gas and water meters, for meter reading purposes and has separate 80A, 25A contactors for control of space and water heating and a 2A triac for tariff switching.
Connection with the Customer Display was via a 4 wire, plug-in cable.

The communication module provided the single phase interface between the home module and the mains.

It contained a clock/calendar, synchronised to that of the Central Controller during polling routines, and permitted switching of space heating and water heating loads at pre-set times.

Non-volatile RAM storage of 1Kbyte permitted a one day storage of incremental meter readings for each utility.

There was a standby battery to enable gas meter and water meter readings to be maintained as well as supporting the non-volatile RAM and the clock/calendar chip.

7.4.3
The Customer Display

The Customer Display had a 10 digit, alpha numeric vacuum fluorescent display and 14 touch sensitive keys.

A series of control and data display functions for each utility were available to the customer including:

1. Display of meter readings including multi-tariff metering.

2. Display of units consumed since last bill.

3. Display of cost incurred since last bill.
4. Display of estimated amount of next bill.

5. Control and display of water heating and space heating on-off times.

6. Clock/calendar.

7.5 Conclusions

The limitations and advantages of these systems are detailed in Table 7.1. As a result of studies of the above trials investigations were undertaken as part of my research project:-

1. RATS (Remote Automatic Tariff Switching).

2. EMBRIO (Energy Management by Real-time Input Output).

7.5.1 RATS utilised the British Telecom radiopaging network for communication with tariff switching equipment located at the consumer's premises. The proposals were not implemented after initial discussions with British Telecom as interfacing and modification of the then standard pagers was not considered economically viable.

7.5.2 EMBRIO was based on the BBC microcomputer and the proposals included the development of both hardware interfaces and software for a 'home computer' to operate as an 'Energy Minder'. A prototype system was developed in June of 1984.
<table>
<thead>
<tr>
<th>Method</th>
<th>Possibilities for Demand &amp; Energy Management</th>
<th>Tariff types</th>
<th>Extras</th>
<th>Limitations</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>No signals</td>
<td>Multi-rate tariffs - time/dependent supply</td>
<td>Preset time of day (or of week) with changes</td>
<td>Local intelligence can be added by A.B. or consumer to exploit tariffs</td>
<td>Limited flexibility - time or condition changes need visit. Time switches need power reserve</td>
<td>Relatively simple. Needed only for suitable loads</td>
</tr>
<tr>
<td>One-way signals</td>
<td>As above, but switching from centres</td>
<td>Flexible - preset or adjustable, day, week, seasonal, or short warning disconnectable</td>
<td>ditto, but can be more complex</td>
<td>Constrained by dist'n network configuration - transmitter serves local area. Supply distortion can be problem</td>
<td>Could be used to control individual consumers. Confined to ESI plant. Need only be installed with suitable loads</td>
</tr>
<tr>
<td>Radio Teleswitch</td>
<td>ditto - and runs as time-switch if not signalled</td>
<td>as for ripple</td>
<td>as for ripple</td>
<td>Low data rate - suitable for signals to groups of consumers, and 'blanket' messages</td>
<td>Nationwide broadcasts with individual A.B. inputs. Signal costs low. Further Med. wave systems are feasible</td>
</tr>
<tr>
<td>2-Way signals Mainsborne</td>
<td>as ripple systems</td>
<td>as for ripple</td>
<td>as for ripple, and return path used for meter reading, tampering detection, bill paying, etc.</td>
<td>Constrained by dist'n network config. Meter reading needs intensive local installation - not all will have suitable loads</td>
<td>Additional consumer attractions can be included, eg burglar alarms, fire detectors. Remote disconnections possible - can address individual consumers</td>
</tr>
<tr>
<td>CALMU</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Table T 7.1

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The proposals for EMBRIO are included here together with details of the hardware interfaces which were produced. The project was most successful and led to the development of MIDAS (Modular Integrated Data Acquisition System) in April 1986. This system was again based on the BBC microcomputer and is detailed in chapter 10.

EMBRIO - Energy Management By Real-time Input Output

Object

To develop a hardware interface for the BBC microcomputer 1 Mhz bus together with an associated software package which will provide user time control for a number of switched inputs and outputs as illustrated in Fig 7.10a.

The following real-time based input/output facilities are to be provided for:

(a) Washing machine / drier
(b) Cooking (slow cooker)
(c) Immersion heater
(d) Heating
(e) Fire alarm
(f) Intruder alarm
(g) Frost detector
(h) Spare

Also consideration should be given to the reading and storage of utility metering, on demand, via the PSTN.

The hardware should be constructed such that it gives adequate isolation between the user port and 1 Mhz bus and also the 240/415 v AC mains supplies.

The software should be user friendly, developed on cassette tape with the final prototype written into EPROM.
NORWEB - 'NIGHTWATCH' - BBC SOFTWARE

T.V. MONITOR

CASSETTE / TAPE

MODEM

RS423 PORT

USER PORT

1MHZ BUS

ADC/DAC

BBC MICRO

SYNTH

INTERBEEB/ITEC INTERFACE

TELEPHONE LINE

FROST DETECTOR

FIRE ALARM

LIGHTING

SPARE

AUDIBLE ALARM

INTP'H 'R ALARM

WASHING MACHINE/DRIER

COOKING (SLOW COOKER) / MICROWAVE

IMMERSION HEATER

HIGH TECHNOLOGY ENERGY MINDERS FROM NORWEB.

ECONOMY 7 AND NIGHTWATCH THE ULTIMATE

T120
The feasibility of developing an enhanced version of EMERIO, on a stand alone basis, with storage of metering information and Bit-Stream 1 utility access should also be considered.

In order to establish the advantages offered by EMERIO the unit should be installed in a suitable domestic environment with careful monitoring of energy consumption on a 'before - and - after' basis.

Feedback from site trials should then be used to fine tune the system.

Advantages

(a) Promotes the sale and efficient utilisation of electrical energy.

(b) Demonstrates that the Board is undertaking cost effective research in the field of Energy Management.

(c) Employs in vogue 'state of the art' techniques which are easily modified (i.e. by software) to provide additional facilities as required.

(d) Fully utilises the 'home computer' concept during hours when the device would, in the vast majority of cases, be unused.

(e) Demonstrates that the Board is prepared to take advantage of current government schemes to the mutual benefit of all concerned (i.e. ITECs as a resource for skills).

(f) Provides a basis for future remote meter reading via dial-up modem links and analogue inputs to the home computer from the utility meters (i.e. electricity, gas and water).
(g) The cost of the Energy Management System is borne by the customer. For example, the customer purchases the ROM and interface unit and the wiring modifications may be undertaken by the Commercial Department.

***

(h) With the assistance of ITEC the system may be developed for a whole range of 'home computers'.

The Overall Philosophy

Consider the BBC microcomputer as the basis for a 'home computer' system which can be utilised on a wide variety of tasks under operator controlled Input/Output.

For example, the printing of letters, accounting, electronic mail, home entertainment and business applications.

To obtain the maximum cost benefit from the purchase of a 'home computer' the system should be utilised, at least in theory, 24 hours per day. However at least 8 hours per day, on average, are spent sleeping and of the remainder a further 7 to 10 hours per day are spent away from the home (i.e. at the place of work).

If the Electricity Supply Utilities consider optimising the sale of electrical energy the best value for money is offered during unsocial hours (i.e. when most people are normally sleeping) when the demand is at a minimum.

It follows therefore that if the computer can be used to control domestic utilisation of electrical energy, according to user pre-defined program timing parameters, the Utilities can harness the 'home computer' as an unsocial hours energy saver, or with reference to a British Telecom press release, as an 'Energy Minder'.

***

ITEC - Information Technology Centre(s)
The SEEBOARD CALMU system is designed to undertake such a function but it is a dedicated device which does not have the flexibility, or the 'Customer Utilisation Incentive', of the home computer.

If the hardware can be built for the BBC microcomputer then, with the assistance of ITECs, the project may be extended to cover a much wider range of microcomputers, the development of software packages and hardware interfaces being of prime importance.

The hardware produced to interface the BBC microcomputer user-port to electrical contactors is illustrated in Figs 7.10b and 7.10c. A software cyclic test routine which was developed to drive the user-port is listed in Table T7.1a.

Conclusions

The EMBRIO experiments proved most successful and the home computer concept was investigated further with reference to the AMTEXT experiments outlined in chapter 8 and detailed in chapter 9.
Fig 7.10b BBC microcomputer user-port interface (EMBRI0)

Fig 7.10c BBC microcomputer user-port interface (EMBRI0)
>L.
  10 A%=&97
  20 X%=&62
  30 Y%=&FF
  40 CALL &FF4
  50 T%=1
  60 Y%=T%EDR &FF
  70 X%=&60
  80 CALL &FF4
  85 PRINT ~Y%
  90 T%=T%*2:IF T%>8 THEN T%=1
 105 FOR I=0 TO 5000:NEXT
 110 GOTO 60
>

BBC microcomputer software cyclic test routine for user-port interface

Table T7.1a Program listing in BBC basic
7.6 
An Analysis of Public Switched Telephone Network (PSTN) Interconnection
for Remote Meter Reading Systems

The principle of idle line telephone interconnection for remote reading of public utility meters is being considered by many organisations. In this analysis some of the fundamental design criteria are examined and compared.

Consider the basic system as illustrated in Fig (7.11).

A basic protocol requires to be established which optimises the reading of meters via the PSTN. Each meter (M) and the associated telephone (T) are assumed to be distributed over a relatively large geographic area and interconnected to the utility central equipment (Master Station) via the PSTN. For the purpose of this analysis it is assumed that:–

1. A meter and telephone (PSTN exchange line) are interconnected such that the meter may seize the local exchange in zero time.

2. That only one outlet is provided from the PSTN to the public utility master station and, therefore, if one of the meters is connected to the PSTN and the master station then all other meters attempting to call get a busy signal returned without delay.

3. The duration of a call includes the set-up and disconnect time.

4. If the master station is free then the calling meter unit begins to transmit without delay.

5. All meters on the system are of the same type, conforming to the same specification.
P.S.T.N. Interconnection for Automatic Remote Meter Reading
6. The overall propagation delay is assumed to be zero.

7. Meters that have had their calls blocked due to faults become independent of their assigned timeslots, and have a higher priority over other meters.

8. Each meter has a store or register which holds the meter reading to be transmitted. When the meter reading target figure is achieved the reading may then be transmitted directly OR held in back-up store for transmission at a specific time.

9. Blocking at the telephone is small (i.e., the idle time is much greater than the in-use voice message time).

Two basic parameters are open to review:

(a) Meters may call at random.

(b) Meters may call in at pre-determined times only.

LET AN = average number of call attempts per successful call with telephone blocking neglected.

AN(b) = average number of call attempts per successful call when the initial attempt is blocked at the telephone where the telephone blocking is assumed small but not negligible.

EC(random variable) = number of extra calls generated when there is a fault at the master station.

ECm = average value of EC.
Two possible packet system protocols are considered and the qualitative parameters of AN, ANb and ECm are determined for each. The following definitions also apply in the analysis:

1. One meter reading is contained in one packet and one packet plus preamble time = one TIMESLOT = Ts.

2. A number of TIMESLOTS = a TIMEFRAME = Tf.

3. VOICE BLOCKING occurs if the telephone is in use when the meter wishes to transmit a reading.

4. PSTN BLOCKING occurs if a meter cannot make a PSTN call to the master station.

5. PACKET ASSEMBLY INTERVAL is the average time which elapses between successive packets being generated at a meter = PAI.

6. YARDSTICK is the fraction of timeslots (Ts units) assigned in a system = Yd.

7. RETRANSMISSION is effected where a meter recalls on the PSTN.

8. RESEIZE is effected when a meter seizes the telephone (i.e. PSTN exchange line) to attempt a RETRANSMISSION.

7.6.1 SCHEME 1

Let there be Tsm (TIMESLOTS) in one TIMEFRAME (Tf) and ALL the TIMESLOTS for K TIMEFRAMES are assigned to the meters followed by one or more empty TIMEFRAMES in order that blocked calls may effect a RETRANSMISSION.
An arbitrating figure for the RETRANSMISSION period is initially set at 1 TIMEFRAME. It follows that a blocked meter waits a pre-determined time equal to Tsm timeslots and then retries.

It should be noted that every meter has a programmed timeslot over the PACKET ASSEMBLY INTERVAL (PAI), and the pattern is repeated over subsequent packet assembly intervals. The packet assembly interval is set by the utility (e.g. 1 month, 1 week, 1 quarter etc).

If there is zero blocking at the telephone then AN = 1.

If, however, a meter is blocked at the telephone then from Fig (7.12) it requires an average of \((K + 1)/2\) retries to send its packet. Now \(Y_d = K/(K + 1)\), therefore:

\[
AN(b) = \frac{1}{2}(1 - Y_d) \quad \ldots \ldots \ldots \ldots \ldots 7.1
\]

To determine the average number of additional calls generated, assuming for simplicity that the fault period lasts for a time equal to some integer multiple \(m\) of \((K + 1)\) Tsm timeslots.

Let \(p = (K + 1)m\) and the fault duration PAI

Ref. Fig (7.12) the number of extra calls (EC) depends upon where in the length of \((K + 1)\) timeframes the fault occurred. At the beginning (i.e. point A) of the timeframe it will be the highest and at the end of the timeframe (E) it will be lowest.

Therefore the average number of extra calls generated is the average or mean of EC say, \(EC_m\) due to a fault at A and \(EC\) due to one at E.
From the above, \( Y_d = \frac{4}{4 + 1} = 0.8 \) and \( T_{sm} = 8 \) slots; \( \square = \text{assigned timeslot} \)

Fig 7.12  FIXED SCHEME

From the above, \( T_{sm} = 8 \) timeslots; \( Y_d = 0.8 \); \( \square = \text{assigned timeslot} \)

Fig 7.13  COIN FLIP SCHEME

Fig 7.14  COIN FLIP SCHEME FAULT

\[ T_i, T_k, T_x, T_{ts} \]

Fault duration

From the above, \( T_{sm} = 6 \) timeslots; \( Y_d = 0.8 \); \( p = 3 \)

\( 1 = \text{blocked call in timeslot} \); \( \square = \text{assigned timeslot} \)
Ref. Fig(7.12) we can calculate the number of extra calls generated for each timeslot in the \((K + 1)\) Tsm, and then to average over the timeslots as follows:

\[A; A + 1; A + 2; A + 3 \ldots \ldots \ldots A + Tsm - 1\]

\[B; B + 1; B + 2; B + 3 \ldots \ldots \ldots E + Tsm - 1\]

Let EC (A) be the number of extra packets generated by a fault at A and in this analysis EC is a deterministic number.

Therefore:

\[
\begin{align*}
EC(E) &= Tsm \\
&= \sum_{i=1}^{mk} \sum_{j+k}^{m-1} \sum_{i=1}^{m-k} \sum_{j=1}^{m-k} \\
&= (1st T) + (2nd T) + (3rd T) + (4th T)
\end{align*}
\]

where (1st T) and (2nd T) give contribution from within fault period and (3rd T) and (4th T) give contribution from outside fault period

Also:

\[
\begin{align*}
EC(D) &= EC(E) + Tsm (m + mK) \\
EC(C) &= EC(E) + Tsm (2m + 2mK) \\
EC(B) &= EC(E) + Tsm ((K - 1)m + (K - 1)mK) \\
EC(A) &= EC(E) + Tsm (km + kmK)
\end{align*}
\]
And a fault at timeslot \( A + i \) produces

\[
(T_s - i) \cdot EC(A) + \frac{i}{T_s} \cdot EC(B)
\]

extra calls ............................................7.3

The first \( (T_s - i) \) timeslots behave as if the fault occurred at \( A \) and the remaining \( i \) slots behave as if the fault occurred at \( B \).

Then, summing over all the \( (K + 1) \cdot T_s \) timeslots, and taking the mean gives:

\[
EC_m = \frac{T_s - i}{(K + 1) \cdot T_s} \cdot [EC(A) + EC(B) + EC(C) + EC(D) + EC(E)]
\]

and reduces to:

\[
EC_m = \frac{T_s \cdot p^2 \cdot Y_d}{2(1 - Y_d)}
\]

From Eq. (4) it may be noted that:

1. The average number of calls grows as the square of \( p \), i.e. as the square of \( (K + 1)m \) and for large values of \( K \) varies as the square of \( K \).

2. \( EC_m \) tends to infinity as the loading factor \( Y_d \) tends to unity.

If a fault of duration \( FL_m \) slots occurs which is less than \( T_s \) slots

Then \( EC_m = \frac{FL_m \cdot Y_d}{2(1 - Y_d)} \) ..............................7.5
In this scheme timeslots are assigned to the meters by flipping a coin (mutually exclusive event) with a success probability of the loading factor, see Fig (7.13). A blocked call queues a pre-determined amount of time equal to $T_{sm}$ time slots before retrying. Designated and undesignated timeslots are uniformly distributed with time. Also, as in Scheme 1, all the meters are designated over one PAI.

Then, if telephone blocking is neglected, $AN = 1$ and a meter that is blocked at the telephone delays any re-transmission (retry) by $T_{sm}$ timeslots. The probability of finding a free slot is $(1 - Y_d)$, since $Y_d$ of the timeslots are occupied.

Then: $\quad AN(b) = \frac{1}{(1 - Y_d)}$ ............................................. 7.6

If $Y_d = 0.8$ for a particular configuration then a meter that is blocked at the telephone requires:-

$$\frac{1}{(1 - 0.8)} = 5 \text{ attempts on average}$$

to successfully call, via the PSTN, to the master station.

Now assuming a fault duration of $pT_s$ timeslots (where $p$ is an integer), commencing at timeslot $T_i$ and ending at timeslot $T_{pT_s}$ where $T_{sm}$ is the pre-determined delay illustrated in Fig (7.14). This implies that the breakdown duration is larger than the pre-determined retransmission delay. The total mean number of additional calls from within, and outside, the fault period may be determined as follows:-
Fig(7.14) shows a group of timeslots denoted Ti.............Tx. A meter that is blocked in timeslot Tk, calls in timeslots Tix + k where i = l.............p-l. The probability that there is another meter scheduled to call in each of these timeslots is given by Yd. Let these similarly placed times form a string Sk = (Tik + k), i = 0.............p-l. Let Sk denote the event that the string Sk has m meter calls in it. Therefore, in the timeslot TpTx + k (this is the kth timeslot outside the period of the fault) there are m blocked meter-calls queueing.

As the fault period is now passed, this queue will reduce by one when an empty timeslot is found, and will remain the same when a utilised timeslot is encountered. Consider first Tsm timeslots and evaluate the additional calls generated for Tsm such strings.

Let ECsi be the sum of the extra calls produced in the string Sj and the additional calls produced outside the period of the fault due to the calls queuing in the string Sj.

As it is assumed that all the strings behave in the same manner

$$ECm = Tsm ECmSj$$

Splitting ECmSj into separate elements we have the following:

**First element** which is given by the number of additional calls generated within the fault period and is given by:

$$P = Yd \sum_{i=1}^{p} i$$
Second element which is given by the average number of additional calls produced outside the fault period by the queuing (blocked) calls in the string $S_j$ and, assuming there are $m$ callers in this string, gives:

$$EC_m S_i = \sum_{m=0}^{p} V(EC_m S_i / S_j) W(S_j)$$

Third element which is given by the majority of queuing calls in the string $S_i$ requiring $n$ timeslots to seize the master station and, assuming there are $m$ calls in the string gives:

$$V(EC_m S_i / S_j) = \sum_{n=m}^{\infty} V(EC_m S_i / S_j(n)) W(S_j(n))$$

where $S_j(n)$ is the timeslot in the string $S_j$ which has $m$ calls queuing in it and requires $n$ tries to empty out. Also

$$W(S_j) = \left(\frac{p}{m}\right) Y_d^m (1 - Y_d)^{p - m}$$

$$W(S_j(n)) = \left(\frac{n - 1}{n - m}\right) Y_d^{n - m} (1 - Y_d)^m$$

Hence, the average number of additional calls $EC_m$ produced outside the fault period is given by:
ECm = \frac{\sum_{m=1}^{P} \sum_{n=m}^{\infty} V\left(\frac{\langle ECmS_i \rangle}{S_j^n}\right) \cdot W\left(S_j^n\right) \cdot W\left(S_j\right)}{m \cdot 1 \cdot m}

Now \( V\left(\frac{\langle ECmS_i \rangle}{S_j^n}\right) = \frac{m(m - 1)}{2} + \frac{(m + 1)(n - m)}{2} \) and

since, there are \( m \) empty timeslots and \( n - m \) occupied timeslots in \( n \) attempts, the timeslot in the last attempt being empty.

Then the total average number of additional calls from both within and outside the fault period is given by:

\[ ECm = \frac{Yd}{2} Tsm p(p + 1) + \frac{Yd^2}{2(1 - Yd)} Tsm p(p + 1) \] .................................................. 7.7

(1st term) (2nd term)

where:

1st term = ECm within fault period and

2nd term = ECm outside fault period

and \( ECm = \frac{Yd}{2} Tsm p(p + 1) \) .................................................. 7.8

\[ \frac{2(1 - Yd)}{2(1 - Yd)} \]
and if the fault period is less than the retransmission delay period (i.e. fault period of FLm timeslots), then:-

\[ ECm = Yd FLm + \left[ \frac{Yd}{(1 - Yd)} \right] YdFLm \]

\[ = YdFLm \left( 1 + \frac{Yd}{1 - Yd} \right) \]

\[ \text{7.6.3} \]

Comparisons between the fixed and coin flip schemes are illustrated in Fig (7.15) for fault durations of between 6 and 24 hours, i.e. the performance of equation 7.8 (fixed scheme) is compared with that of equation 7.9 (random scheme) over a 24 hour period.

It can be seen that the fixed scheme gives better performance than the random scheme and for a long fault condition, say 24 hours, the random scheme generates an additional 14400 retries, or an additional 20% compared with the fixed scheme. In this analysis the fault period is assumed to last for a duration much less than the PAI but equal to or greater than one time frame (Tf) of Tsm time slots.

If we now compare the two schemes when the fault period is less than one time frame, of Tsm time slots, then the performance of equation 7.5 (fixed scheme) should be compared with that of equation 7.9 (random scheme).

For example if a system has Yd = 0.8, Tsm = 360 time slots, and p = 5, then the fixed scheme generates 120 retries whereas the random scheme generates 240 retries. Therefore, once again, the fixed scheme gives better performance.
Fig 7.15

Coin Flip Scheme

Fixed Scheme

Additional Retries Generated (No Off)

Duration of Fault Period (Hours)

(1 Day)
CHAPTER 8

THE INTELLIGENT HOME AND THE CUSTOMER BILLING INTERFACE

8.1 Introduction

The RATS and EMBRIO case studies detailed in Chapter 7 highlighted the feasibility of utilising the 'home computer' to develop the 'Intelligent Home' concept in which remote meter reading and load control are only two of the facilities which may be provided for via such a system of telematics.

8.2 The Key Areas

The following key areas were identified as a result of the Embrio case study.

1. Communications

2. Education and Entertainment (radio, television, computer games etc)

3. Accounting and Record Keeping

4. Energy Control

5. Meter Reading (electricity, water, gas)

6. Security

7. Environmental Control.

8. Lighting Control
9. Air Conditioning

10. Fire Detection

11. Domestic Appliance Control

12. Working at home (Telecommuting)

The concept is illustrated in Fig. (8.1).

A BBC computer was utilised as the 'test bed' for software development, in each of the 12 key application areas stated, with particular emphasis being placed on communications as detailed in Chapter 9. The design and development strategy is detailed in Figs 8.2, 8.3 and 8.4.

The intelligent home philosophy is becoming more of a reality as communications systems develop and integrate (see chapter 2). The home computer originally marketed on its entertainment value (computer games etc) can now provide facilities in all of the 12 key areas specified.

8.3 The issues influencing the adoption of telematics

There are many important issues which it is considered will influence the adoption of telematics in the home and they may be summarised:

(a) House prices in certain areas of the country are essentially prohibitive and prevent companies from obtaining the right staff in the right locations.

(b) Many workers commute for anything up to four hours per day.
The Intelligent Home Concept.

Fig 8.1
CONCLUSIONS

LIST ADVANTAGES & DISADVANTAGES OF MODULAR SYSTEM OVER 'BENCHMARK'

START

CONSIDER GENERAL TECHNIQUES

CONSIDER AN EXISTING KNOWN SYSTEM AS A 'BENCHMARK'

DEFINE ESSENTIAL COMPONENTS OF 'BENCHMARK'

DETERMINE ADVANTAGES & DISADVANTAGES

CONSIDER VARIOUS SYSTEM COMBINATIONS AND PERMUTATIONS

DOES 'BENCHMARK' ADAPT?

NO

AVOID SHORTCOMING OF 'BENCHMARK'

DOES 'BENCHMARK' ADAPT?

YES

DETERMINE REASON FOR FAILURE TO ADAPT

IS 'A BETTER BENCHMARK' KNOWN?

NO

COMMENCE BASIC MODULAR SYSTEM DESIGN

COMPARISON BASIC MODULAR SYSTEM WITH THE 'BENCHMARK'

LIST ADVANTAGES & DISADVANTAGES OF MODULAR SYSTEM

CONCLUSIONS

END

Fig 8.2

N.B. Benchmark = Reference System
THE PROBLEM DUE TO A FUNDAMENTAL ERROR?

DESIGN OF MODULES COMPLETED

YES NO

DESIGN OF MODULES COMPLETED

CHECK CIRCUIT, WIRING, LAYOUT, AND ALL COMPONENTS

IS THIS THE FINAL MODULE?

YES NO

DOCUMENTATION OF MODULE DESIGN

ARE ALL PARAMETERS MET?

YES NO

FINAL TEST

FINAL DESIGN

ARE ALL PARAMETERS MET WITH THIS DESIGN?

YES NO

CIRCUIT PARAMETERS MET WITH THIS DESIGN?

CHECK CIRCUIT IN DETAIL

IS THE PROBLEM DUE TO INCORRECT CALL OF COMP. VALUES?

YES NO

RE-ARRANGEMENT, REDUCTION OR ALTERATION OF COMPONENTS AND STILL MEET REQ'D PARAMETERS?

CAN THE CIRCUIT COST BE REDUCED BY ANY RE-ARRANGEMENT, REDUCTION OR ALTERATION OF COMPONENTS AND STILL MEET REQ'D PARAMETERS?

NO

YES

MODIFY CIRCUIT AS REQUIRED

INITIAL TEST

BUILD BREADBOARD CIRCUIT

DECIDE REQUIRED PARAMETERS & CALCULATE COMPONENT VALUES

STUDY AVAILABLE LITERATURE

DECIDE MODULE TO BE DESIGNED

DOCUMENTATION OF MODULE DESIGN

CHECK CIRCUIT WIRING, LAYOUT AND ALL COMPONENTS

to fig 8.2

START
START

INPUT CALL SIGN

SELECT PROTOCOL
  VADCO/TAPR/BB/C

SELECT SPEED (DOWNSIZE)
  RX

SET RS423 FOR 380 B

5

INPUT TEXT TO
AN ARRAY

PRINT TEXT
PRIORITY TO TRANSMISSION?

PRINT ROUTINE

WAIT LOOP

CHECK CHANNEL MODE ROUTINE

SET TX PROTOCOL
  VADCO/TAPR/BB/C

TX ROUTINE

APPLY ACKN ROUTINE

4

SET UP ACKN
MESSAGE

2

OUTPUT MESSAGE
IS ACKN?

RESET BUFFERS & EXIT RX MODE

PRINT routine
"MESSAGE RECEIVED"
(c) Many of our road systems cannot cater for the 'peak time' traffic as a result of daily worker immigration to and migration from urban (city) centres of employment.

(d) Business premises financial overheads in large cities have reached a point where recently, in London, a bank moved into new accommodation at £62.50 (1988) per square foot only to realise space occupied by waste-paper baskets now costs as much to rent each quarter as the baskets themselves cost in the first place.

(e) The Henley Centre for Forecasting published the results of a recent survey which indicated that:

1) 48% of us would prefer to work independently of other people, 21% would not prefer to do so and 31% were indifferent or undecided. Also 65% said they would prefer to choose their own hours of work rather than have the routine and discipline of regular hours. The report concludes that besides money, work fulfils other needs such as structure and time disciplines, friends and social contacts, a wider purpose in life, personal status and self-improvement.

2) By 1995, 49.7% of employees and 43% of the self-employed could be doing some telecommuting.

3) With just 20% of all work being done at home it is estimated that individuals would save £270 million a year on fares and car-running costs; the reduction in road casualties would amount to an equivalent of £93 million net benefit to society, and individuals would enjoy on average an extra 38 minutes a day (one hour in London) free time if they didn't have to commute.
(f) The inclusion of suitable electrical interfaces on many domestic appliances such as TV receivers (i.e. SCART sockets), Hi-Fi equipment including VHF FM/AM radio receivers, water heating, space heating and air conditioning systems, washing machines, cookers etc.

(g) The development of a national telecommunications infrastructure based on the integrated systems digital network (ISDN) concept.

(h) The personal telephone concept.

(i) Advances in mobile radiotelephone systems design and the cellular network concept.

(j) Emerging standards of interconnection at all levels (e.g. OSI 7 layer model).

(k) The need to utilise our energy resources as efficiently as possible.

(l) The need to continually educate and re-educate a work force.

(m) The acceptance of 'distant learning' as an efficient and economic system of education at all levels.

(n) The universal adoption of the computer and computer systems.

(o) The 'real time' utilisation of the home computer (ref. EMBRIO Chapter 7).

(p) The fact that all the 'key areas' previously identified can be defined in software and hardware interconnected as necessary via standard pre-definable electrical interfaces (e.g. RS423, IEEE BUS etc).
(q) The advent of Electronic Fund Transfer (EFT) and Point of Sale Electronic Fund Transfer (POSEFT). Both of which have demanded high security computer transaction techniques and standards.

The home computer may also be fully utilised (24 hours per day) making its inclusion in the home extremely economic when compared to the overall cost of a house, especially in the South of England. The need is to develop a set of standards to permit transactions via the national telecommunications networks for energy metering and domestic load control information.

The ESI Customer Billing Interface (see Chapter 5) then requires to be modified for it becomes feasible for the customer's bill to be generated locally and his financial account (bank, building society etc) to be debited directly by the energy supplier, subject to perhaps random security checking by the supplier as and when necessary.

Eng.105/A/1.75
CHAPTER 9

TEXT, COMMUNICATIONS AND CONTROL SIMULATION ON THE BBC MICROCOMPUTER

9.1 Introduction

In the course of practically investigating the home computer philosophy it became necessary to consider three main areas of application:

1. Text processing.
2. Interfacing for control purposes
3. Communications.

With limited work space (memory) in the BBC model B microcomputer it became necessary to investigate each area separately and to compromise overall.

9.2 Communication

Considering the communications aspect first the BBC machine had an integral modem and AFSK tape input-output interface which it was considered might interface directly with a VHF radiotelephone unit. Early tests proved this was possible, though perhaps not ideal. It then became necessary to investigate a protocol for similar machines to communicate via a VHF or HF radio channel.
Packet Approach

A 'packet' approach was considered appropriate based on the Aloha concept and the Advanced Research Projects Agency (ARPNET) Network in the USA which consisted essentially of a collection of small computers scattered across America linked by moderately fast landlines (about 50 kbits/sec). Client computers were connected to the nearest network computer and could then launch data into the system. These packets were routed through a sequence of computers to their ultimate destination, giving the name 'packet switching' to this sort of network.

The main object here was to test out simulated transmission of any general text via a radio telephone network with each text message being broken down into a number of data packets and these packets being transmitted during the channel idle periods (i.e. with no voice traffic present).

The involvement of radio communications in this experimental mode of the project suggested that local 'Radio Amateurs' might prove to be of assistance in the process of 'on-air' testing and development of the communications software.

Such indeed was the case and it was with the assistance of members of the Westmorland Radio Society that much of the software was initially air tested subsequently modified and refined.

A summary of the development of AMTEXT(Adaptive Microcomputer based Terminal for Experimentation in the Transmission of Text) software and hardware, together with the details of the subsequent VHF and HF tests, is detailed in the following section.
2.4 System Design Strategy

The System Design Strategy may be divided into the distinct areas of hardware and software development. A major objective was to keep additional hardware requirements to a minimum, as detailed in chapter 8 and illustrated in Fig. 8.3. As a result hardware development was undertaken first.

This approach would permit software testing to be carried out directly over the radio communications channel, as and when required, all the necessary interfacing hardware already having been constructed. The proposed system was to be 'software orientated' therefore the development of programs should constitute the major part of the experimental work.

2.5 Hardware Development

From a hardware point of view the simplest form of interconnection between the computer and the radio transceiver was via the computer cassette port. Any existing cassette based software could be utilised to test software teleloads and dumps over the radio communications channels at 300 and 1200 bauds. The only remaining problem would be to develop software to access the cassette tape port with user data in a protocol other than that utilised for program storage on cassette tape. Reference to the available literature on the BBC computer suggested that this should be possible and with this in mind interfacing of the computer to the FM transceiver via the cassette port was undertaken. Should the cassette port interface prove unsuccessful then the more conventional RS423 serial data port was to be employed and a small modem designed to provide the interface with the FM transceiver.
9.5.1 Cassette Port Interfacing

Initially simple tests were undertaken to determine the relevant parameters of the cassette recorder port. The waveforms output from the cassette port, as observed on a storage oscilloscope, are illustrated in Fig. 9.1. As can be seen there are two major frequency components, one at 2400 Hz and the other at 1200 Hz. The amplitude of the signals remained constant at approximately 160 mV peak to peak irrespective of the frequencies present and without appreciable distortion or reduction in amplitude when loaded down to 1000 ohms.

The first practical interface consisted of coupling the cassette port data out line directly into the transceiver microphone input via a 6.8 mfd capacitor and a 10 kohm potentiometer. Similarly the cassette port data in line was connected via a 0.033 mfd capacitor to an extension speaker unit normally used with the IC240 transceiver. For test purposes the transmit switching was via a remote switch off the transceiver PTT line. The interface wiring was extremely simple consisting of screened leads and a small die cast box housing the potentiometer and TX switch. The results obtained on teleloading and dumping of programs was most encouraging the only problem being a limitation of the transmission speed to 300 bauds and manual operation of the TX switch. The computer would not accept data at the 1200 baud rate over the radio channel due, as far as could be determined, to the overall amplitude-frequency response of the 2mtr. transceivers employed for the tests. It was decided to accept the 300 baud transmission rate initially and provide automatic transmit switching of transmission speed later.
The above were as observed with the output of the cassette port terminated in a high impedance (>1Mohm). Negligible variation results, both in amplitude and waveform contour, for resistive loads down to 1 k ohm.

N.B. Approximate rms value of output voltage is 57 mV.
The initial tests on the cassette port also revealed that it was not possible to read data into the port without the cassette motor relay being operated. This was found to be a feature of the architecture of the BBC computer serial ULA (uncommitted logic array) which uses a carrier detection circuit to detect gaps between the data blocks on the cassette recordings. A block start is only recognised after the detection of a carrier (2400Hz tone). If a corrupted block start is received the cassette motor is stopped and then started to force another block start. The serial data system assumes that the cassette port is always receiving data via the cassette tape deck and not, as in the case of AMTEXT, from a radio receiver.

This situation was disappointing as it implied that the 2 mtr transceiver PTT line could not be simply connected to the cassette motor relay in order to key up the Tx, as and when required, under program control. Fortunately the cassette port would output data without the need for the cassette motor relay to be operated. However, it was also noted that when the RS423 port was configured, under software control, to the cassette port another problem arose in that as soon as data carrier was detected at the data input side of the cassette port a similar carrier was returned on the output side.

It was decided that if, in the data transmit mode, the presence of transmit data could be detected by some form of VOX (i.e. voice frequency operated switch) and the output of this VOX utilised to switch the PTT line of the transceiver then in the data receive mode the cassette motor relay operation could be used to inhibit the operation of the VOX thus overcoming the cassette port handshake problem. A suitable VOX was designed, with commonly available components, as part of the overall interface requirement (see Fig9.2) and re-titled a data stream switch (DSX), a title which, it was considered, best described its purpose.
9.5.2 Interface Construction

As can be seen from Fig.9.2 the only major item requiring construction is the DSX. This voice frequency switch consists of a 741 op.amp. driving a pair of bi-polar transistors. Transistor TR2 has relay RLI as a collector load with a single make/break, normally open, contact set. A similar relay RL2 with a normally closed contact set is also provided. The input impedance of the 741 was set at 10kohm via R1 and the voltage gain at 4.7 via R2 where voltage gain = R2/R1. The output of the 741 is then fed to the base of TR1 via C3. The dc potential of the base of TR1 is normally held at approximately 0.42 volts by R5 and R6 this being the base potential of TR1.

When a signal with an amplitude greater than 38mV is applied at the 741 input the positive excursions of the signal drive TR1 on (i.e. the base of TR1 exceeds 0.6volts w.r.t. to the emitter). This in turn causes a negative going composite signal to be applied to TR2 base and this transistor is also turned on. Capacitor C4 acts both as a dc bias reservoir and a delay timing element. The value of time delay being dependent on the values of C2 and the coil resistance of relay RL1. With a coil resistance of 500ohms for RL1 the value of C4 was set at 10mfd. This gives an adequate turn off delay for the switch so as not to drop the TX carrier off during MCW identification transmission of the user stations call sign when operating in the AMTEXT mode.

The DSX unit was housed in a die cast box and interconnected to the computer and radiotelephone unit via flexible multicore leads and sockets. A typical unit is illustrated in plate 3 and a suitable power supply may be included if required. Such an internal power unit is illustrated in the left hand side of plate 4, the DSX printed circuit board being positioned in the lid of the die cast box as shown on the right hand side of plate 4.
All interconnections between the computer cassette tape port and the transceiver microphone and speaker sockets are via screened cables with in-line jack plugs and sockets provided in the extension speaker, TX microphone and cassette motor control leads such that during other applications of the computer or when reverting to the normal speech mode on the transceiver a simple means of re-configuring connections was available. Relay RL2 is energised via the cassette motor control output from the computer when operating in the AMTEXT mode. It is included to inhibit TX key up during data receive periods which would occur due to the handshake operation of the cassette port when configured to the RS423 system. It should be noted that when a data carrier (i.e. 2400 Hz tone) is detected on the receive line of the cassette port a similar 2400 Hz tone is returned down the transmit side of the cassette port, this of course would operated the DSX and key up the TX carrier via the PTT line and thus would inhibit the data RX signal and an unstable situation would result. Such a situation is prevented from arising as the contacts of RL1 and RL2 are wired in series.

9.5.3 Minimising Interface Cost

The DSX was built with inexpensive, commonly available components. Relays RL1, RL2 are minature reed types which could contribute to 85% of total DSX component cost. To overcome this, solid state switching of the transceiver PTT line was also developed as shown in Fig.9.3, however care should be taken to avoid switching PTT (Press To Talk) transmitter loads which might apply high reverse voltages to TR3 resulting in breakdown of the semiconductor junctions. During two hundred hours of 'on-air' testing both types of DSX were utilised, on a wide variety of commercial VHF and HF radio transceivers, without failure. Fig.9.4 illustrates the major hardware components, including the DSX units, as required for a 'two station' AMTEXT experimental radiotelephone data link.
ALTERNATIVE SOLID STATE P.T.T. SWITCHING

AS FIG 9.2

To cassette motor control relay on cassette port.

Fig.9.3

NB CARE SHOULD BE TAKEN AS TO THE LOAD PARAMETERS WHEN EMPLOYING SOLID STATE SWITCHING.
AMTEXT - TRANSMISSION SYSTEM (Two stations only)

Fig. 9.4

Schematic of Hardware Illustrating Interconnection of Major Components
9.6

Software Development with reference to 'AMTEXT-1' Packet Simulation Program, Specification and Listings in Appendix 1

The following were considered the key areas of program development:

1. Text input, edit and print facilities.
2. Transmission PROTOCOL (i.e. Data Packet Structure) and the TRANSMIT routine.
3. MULTIPLE USER ACCESS to a common radio channel.
4. Failsafe timeouts and error check facilities.
5. GENERAL and SPECIFIC (PACKET) receive modes with on-line print option.
6. Level setting, test and diagnostic facilities.

9.6.1

Text Input, Edit and Printout Facilities (Prog. List. Lines 420/730)

It was decided to adopt keyboard text entry and screen edit prior to transmission. The message text, in the form of alpha-numerics, being input to an array from the keyboard before transmission. A hard-copy of the text being output to the printer, before transmission, if requested by the user. It should be noted that the printer utilised, on the experimental system, was an EPSON MX-80F/T3 and the associated line-feed code (Prog. List. Line 80) was for this machine.
9.6.2

In order to comply with the UK Radio Amateur licence requirements for experimental data transmission, it was decided to utilise a PROTOCOL consisting of BIT PATTERNS as described in the ASCII code. The protocol illustrated in Fig. 9.5 was chosen, this being considered a basic minimum, to permit PACKET working with full acknowledgement facilities. There are two basic types of data packet employed, a MESSAGE PACKET and an ACKNOWLEDGE PACKET, each one utilising the same synchronisation (SYNC.) and end of text (E.O.T.) characters. The message packet also has variable address and text field whereas the acknowledge packet has the ASCII code characters 'ACK' followed by 'QSL de CALS' i.e. a confirmation (QSL) of receipt of message packet from the recipient station.

In order that the message packet ASCII character may be output from the BBC microcomputer to the radio transmitter via the tape cassette port the RS423 serial system requires to be reconfigured under software control (Prog. List. Lines 760/880). The electrical characteristics of the cassette port also require to be set with regard to the DATA CARRIER PREAMBLE and LAG, i.e. the data carrier ON TIME prior to modulation by the data and the data carrier TURN OFF DELAY at the end of the data packet. After experimentation with regard to TX RISE TIMES, the data carrier preamble and lag times were set as illustrated in Fig. 9.6.
AMTEXT - Packet Format

Call sign CHAR STRINGS 'ADDS' de 'CALS' address field

N.B. The synchronisation 'SYNC' and end of text 'EOT' characters may be output as $\frac{1}{2}$ or $\frac{1}{3}$ depending upon SCREEN MODE selected.
DATA PACKET
(1200/2400 Hz)

2400 Hz data carrier

2400 Hz data carrier

Data Carrier Preamble & Decay Times

Fig. 9.6
It should be noted that after reconfiguring the RS423 serial system to
the cassette port, via operating system commands, it should be reset to
its original state immediately the data packet transmit routine has
been executed. Once again this is achieved by utilising the
appropriate operating system commands (Prog. List. Lines 1210/1240).

The MCW identification routine (Prog. List. Lines 1080/1170) permits
the data carrier (2400 Hz tone) to be keyed on and off to enable the
originating station's call sign to be appended to each message packet
if required. Four periods are defined for this purpose (i.e. DASH,
DOT, SPACE and PAUSE) each one being defined as a tone on or off period
(Prog. List. Lines 2170/2320).

It should also be noted that the experimental call sign utilised,
(le G3WRI) is defined in MCW (Prog. List. Lines 110 'G'; 110 '3'; 1130
'W'; 1140 'R'; 1150 'I') within the program and other users must amend
the appropriate lines to generate their own call sign before using the
program 'ON-AIR'. The full MCW appendage is 'de G3WRI K'.

9.6.3
Multiple User Access to a Common Radio Channel

One of the major advantages claimed for packet radio systems is that
the average traffic on a given radio channel may be increased several
(103)(104)
fold. In order to optimise traffic (data packets) on a given radio
channel the following points were considered to be of particular
significance:
1. Minimising redundancy within the data packet (i.e. as many characters as possible within the data packet should carry message text, those carrying synchronisation, address, error detection and end of text information should be minimised).

2. As many packets as possible should be transmitted per unit time (i.e. Data packets should be serialised such that a minimum idle time exists between adjacent packets).

3. The modulation rate should be such as to take full advantage of the available channel bandwidth.

4. Acknowledge packets should be of minimum length.

5. Simultaneous packet transmissions by users (i.e. Resulting in call collision) should be minimised.

6. A channel access protocol should be adopted and in its most basic form should consist of a LISTEN ON CHANNEL, if free, TRANSMIT, if busy, WAIT UNTIL FREE. Also, in the receive mode, only a station in the SPECIFIC (PACKET) mode, when correctly addressed, should output the message text to the screen or printer.

7. In order to observe ALL PACKET TRANSMISSIONS on the radio channel a GENERAL receive mode should be included. In this mode all message packets irrespective of their destination or source addresses should be output to the screen or printer.

N.B. This particular area of program development was considered to be one of the most challenging to optimise for Radio Amateur type 'RANDOM ACCESS COMMUNICATION'.
9.6.4

Failsafe, Timeout and Error Check Facilities

In order to time limit certain operations timeout loops are incorporated in the program. Should any loop be traversed more than a given number of times then the routine is reset or escaped from (Prog. List Lines 1890/1970).

Error check facilities have been minimised to reduce redundancy and no frame check sequence or checksum is incorporated in the data packets. However a check is made on the received data packet ASCII characters to ensure that they fall within the correct range (Prog. List. Lines 1920/1950) and any corrupted characters which might appear as control characters are rejected by the system and a banner headline is displayed (Prog. List. Line 2380) to indicate a corrupted message. The acknowledge packet transmission routine is also inhibited and the appropriate receive mode is reset.

9.6.5

General and Specific (Packet) Receive Modes with On-line Print Option

Prog. List. Lines. 1290/2100).

In order to provide general listening facilities, without possible acknowledged packet transmission, two receive modes are incorporated in the program. When the program is loaded and run a receive interrupt assembler routine (Prog. List. Lines 100/270) first sets event vectors such that on a data carrier detect at the cassette port (i.e. 2400Hz tone ON, see Fig. 9) memory location address &B0 is set to 0. This permits the system to commence reading packet ASCII characters, input via the cassette port, after the data carrier preamble has been detected.
In order that the data packet ASCII characters may be input to the BBC microcomputer from the radio receiver via the tape cassette port, the RS423 serial system requires to be reconfigured under software control (Prog. List. Lines. 1410/1470).

In both receive modes the first data packet character is for synchronisation purposes and must be received correctly to permit the receive routine selected to continue through to screen display (Prog. List. Line 1760 tests to see if the SYNC character is present and also that memory address &B0, which has been reset to 0 after DCD, is still = 0).

If the SPECIFIC (PACKET) Rx mode is selected then the next group of ASCII characters, which form the address field, are tested to see if they conform to the station address (Prog. List. Lines 1790/1830). If any address characters fail to match the receive mode is exit and reset. If however ALL THE CHARACTERS in the address field match the user's call sign then a header (Prog. List. Line 1880) is output to the screen. Each additional text character is then tested in turn to see that it's ASCII value falls within the print character range (Prog. List. Lines 1920/1950) and, if such is the case, are output to the screen or screen and printer as required by the user. When the final packet character (end of text E.O.T.) is detected or the timeout period is exceeded (Prog. List. Line 1970) a terminating banner is output to the screen (Prog. List. Line 2000) and the receive routine is exit.

Assuming a valid message has been received in the SPECIFIC (PACKET) mode the ACKNOWLEDGEMENT routine commences and the acknowledge packet is returned to the station originating the received message packet.
The GENERAL Rx mode is similar to the SPECIFIC mode but the address 'STRIP-OFF' routine is omitted and all data packets are output to the screen. Also, in this mode the acknowledge packet routine is inhibited. The first data packet character is for synchronisation purposes and must be received correctly to permit the receive routine selected to continue through to screen display (Prog. List. Line 1760 tests to see if the SYNC character is present and also that memory address &B0, which has been reset to 0 after DCD, is still = 0).

It should be noted that the experimental call sign, G3WRI, is set up in program lines 1790/1830. In order for other program users to receive message packets in the SPECIFIC (PACKET) mode, which have been addressed to them, program lines 1790/1830 MUST BE AMENDED accordingly.

9.6.6
Level Settings, Test and Diagnostic Facilities

In order to provide a relatively simple means of setting up the system hardware a number of test and diagnostic routines were developed to assist the experimental work:

1. Transmitter Audio Input Level Set (TAILS).
   This program, listed in Fig.9.7, is designed to output a continuous 2400Hz data carrier from the BBC microcomputer cassette port to enable level setting via potentiometer RV1, illustrated in Fig. so as to provide the correct audio input level to the transmitter. ASCII TEST PATTERNS are also provided.

NB. IT IS IMPORTANT THAT THE TX AUDIO INPUT LEVEL IS SET BEFORE RUNNING THE AMTEXT SYSTEM PROGRAM SO AS TO PREVENT POSSIBLE OVER-MODULATION PRODUCTS FROM BEING GENERATED AND CAUSING INTERFERENCE TO USERS ON ADJACENT CHANNELS ETC.
10 ON ERROR GOTO 430
20 MODES=VDU19,0,4,0,0,0
30 REM G3WRI 'ANTEIT' TX TEST AND LEVEL SET ROUTINES 1, 2 AND 3
40 REM Copyright 'PO8 SYSTEMS Kendal England' (C) 1984.
50 P$="1:U$="2:V$="3"
60 CLS
70 PRINT"*************** A G3WRI 'ANTEIT' PROGRAM FOR THE BBC MICROCOMPUTER ***************"
80 PRINT"*************** Copyright (C) 1984 PO8 SYSTEMS Kendal England U.K. ***************"
90 PRINT"*************** Transmit Audio Input Level Set program ***********************"
100 PRINT"*************** T A I L S ***********************"
110 PRINT"M.B. THIS PROGRAM SHOULD BE RUN AND THE TX AUDIO INPUT LEVEL SET PRIOR TO USING G3WRI 'ANTEIT' ON-AIR. ALL TEST TONES/PATTERNS ARE OUTPUT AT THE CASSETTE PORT."
120 INPUT"Do you require:" 1. A continuous DATA CARRIER TONE (2400Hz)** 2. A SET PATTERN of MODULATION (i.e. **** etc.)*** 3. A VARIABLE PATTERN of MODULATION (i.e. ALPHANUMERICS etc.)**"ENTER 1, 2 or 3 as required.""TYP$"
130 IF TYP$=P$ THEN 190 ELSE 140
140 IF TYP$=U$ THEN 160 ELSE 150
150 IF TYP$=V$ THEN 160 ELSE 120
160 INPUT"Do you require:" 1. A MODULATION RATE of 300 BAUD*** 2. A MODULATION RATE of 1200 BAUD**"ENTER 1 or 2 as required.""SPD$"
170 IF SPD$=P$ THEN 190 ELSE 180
180 IF SPD$=U$ THEN 190 ELSE 160
190 *FI 2,2
200 *FI 205,64
210 IF TYP$=P$ THEN 230 ELSE 220
220 IF SPD$=U$ THEN 260 ELSE 230
230 *FI 7,3
240 *FI 8,3
250 GOTO 260
260 *FI 7,4
270 *FI 8,4
280 *FI 203,9
290 IF TYP$=P$ THEN 330 ELSE 340
300 PRINT"*************** DATA CARRIER 'ON' (2400Hz tone) ***************"
310 TIME=0
320 REPEAT UNTIL TIME=6000
330 GOTO 430
340 *FI 3,1
350 IF TYP$=U$ THEN 360 ELSE 400
360 TIME=0
370 VDU 42
380 IF TIME<6000 THEN 370
390 GOTO 430
400 TIME=0
410 PRINT"1234567890QWERTYUIOPLASDFGHJKLZXCVBNMQwertyuiopasdfghjklzxcvbnm.,/[:@\~'#$%^&*()+=|<>?""
420 IF TIME<6000 THEN 410
430 *FI 3,0
440 *FI 203,255
450 *FI 205,0
460 *FI 2,0
470 *FI 21,1
480 *FI 15,0
490 PRINT"***** TIME UP 'RUN' PROGRAM AGAIN IF TEST TONE/PATTERN STILL REQUIRED *****"

These programs, listed in Figs. 9.8 and 9.9, permit a user to listen on channel to all ASCII characters sent in order to check the protocol (i.e. DATA PACKET STRUCTURE). It should be noted that the GENERAL Rx mode can be used for most purposes but if there are problems with DCD (DATA CARRIER DETECT) or the synchronisation character is changed then the GENERAL Rx mode will no longer display the received ASCII characters on the screen.

N.B. USERS SHOULD TAKE CARE WHEN USING MAC AS CONTROL CHARACTERS CAN BE FED TO THE SCREEN WITH STRANGE RESULTS. EXIT THIS PROGRAM WITH A 'BREAK' COMMAND FROM THE KEYBOARD.

The AMTEXT Timing Chart is illustrated in Fig. 9.10 for both the MESSAGE PACKET and the ACKNOWLEDGE PACKET. Also an experimental H.F. (3.75 MHz) 300 baud (bits/sec) Packet Frame Format is illustrated in Fig. 9.11. The H.F. experiments were conducted to evaluate possible 'Mailbox' applications over 100 to 500 mile hops. A number of test message print-outs, as received from the distant stations, are included in Appendix 2.

9.6.7 Summary

The AMTEXT experiments included a total of 300 hours of 'air-testing' and the following are considered to be prime areas for further development:

1. Error detection by the inclusion of an additional Frame Check Sequence byte, in the protocol, which has been calculated from the contents of the text field.

2. The inclusion of an additional control byte, in the protocol, to enable such information as message packet number, data type, text field format, etc. to accompany each message packet. This
10 REM G3WRI 'AMTEXT' DIAGNOSTIC ROUTINE
20 REM Monitor ASCII Characters 'MAC'
30 REM This program is a 300 BAUD ASCII RX routine.
40 *FX205,64
50 *FX7,3
60 *FX8,3
70 *FX156,3,252
80 *FX156,2,252
90 *FX137,1
100 *FX2,1
120 REPEAT: IF(?&FE08 AND 1)=1 VDU(?&FE09 AND 127)
130 A$=INKEY$(0): IFA$<>"" ?&FE09=ASCA$: PRINTA$;
140 UNTIL0

Fig.9.8

10 REM G3WRI 'AMTEXT' DIAGNOSTIC ROUTINE
20 REM Monitor ASCII Characters 'MAC'
30 REM This program is a 1200 BAUD ASCII RX routine.
40 *FX205,64
50 *FX7,3
60 *FX8,3
70 *FX156,3,252
80 *FX156,2,252
90 *FX137,1
100 *FX2,1
110 *FX156,1,252
120 REPEAT: IF(?&FE08 AND 1)=1 VDU(?&FE09 AND 127)
130 A$=INKEY$(0): IFA$<>"" ?&FE09=ASCA$: PRINTA$;
140 UNTIL0

Fig.9.9
AMTEXT - Timing Chart

Initiate Tx (i.e., on depression of 'RETURN' key; time 't' = 0)

Listen on freq. Message Tx prior to Tx time MCW ident.

if req'd

Message Packet Transmit

A

B

C

D

E

F

G

H

t=0

'A' variable from 1 to 35 secs
'B' fixed at 750 msecs
'C' variable to 5 secs max
'D' fixed at 250 msecs
'E' fixed at 500 msecs
'F' variable to 10 secs max
'G' fixed at 1 sec
'H' variable 2 to 70 secs (at 300 baud)

1. If transmission 'NOT' acknowledged sequence t - C to t - 1 repeated

2. If acknowledgement 'REC'D' select Tx/Rx mode is output to VDU screen

Send ACK ROUTINE in progress' output on VDU

Yes

MCW ident Rx blanking if Listen on freq req'd prior to Tx

Tx ACK packet Specific Rx packet mode

N. N. The above are not drawn to scale

Initial timing format for AMTEXT protocol - 1
AMTEXT HF (3.75 MHz) Experiments (HF Packet Frame Format)

30C baud (bits/sec) HF Packet Designed for HF Mailbox Evaluation

HF Test Packet Frame

Main Data Burst Field

Tuning Field

Pretone Field

'AMTEXT Data' in CW/MCW at 2400 Hz

Listening Period 10 to 20 secs then Test Packet Frame is Repeated

Station Ident. Field "de G3WRI K" in CW/MCW at 2400 Hz

Transmission commences

Overall Test Packet time (16 - MDBP) to (32 - MDBP) secs

MDBP (Main Data Burst Period)

Fig. 9.11
should permit the transmission of program data and alphanumeric text without the need to resort to the 'SAVE' and 'LOAD' routines of the BBC microcomputer.

3. Multi-message packet working permitting the formation of a message packet field with a fixed number of bytes and a corresponding variable number of packets per message.

4. Split screen, real time, input output as an option.

5. Multi-protocol AMTEXT software to include AX25, VDTDCG and BBC.

6. Multiple-user access routines to optimise common radio channel working.

7. Computer controlled H.F. search and tuning routines for use in conjunction with microprocessor controlled transceivers with remote incremental tuning facilities.

8. Experimentation to determine the optimum values of certain protocol parameters for efficient H.F. working. In particular speed of transmission versus maximum usable frequency.

9. The development of a Modular Integrated Data Acquisition System (MIDAS) based on both Local and Wide Area Networking (LAN-WAN) by packet radio repeaters utilising the concept of idle time working.

10. The adoption of interconnection standards to facilitate modular system development and upward compatibility.

Items 9 and 10 above are considered in some detail in chapter 10 together with the cellular concept for both local and wide area networking utilising existing UK ESI VHF radiotelephone channels.
9.4 Text Processing

Text processing facilities (prior to transmission) were incorporated in the AMTEXT software together with word-processing packages all of which are detailed in Appendix (1).

9.5 Interfacing for Control Purposes

The ability of the BBC machines to operate external devices under stored program control was demonstrated via the EMBRIO study of Chapter 7 and as a consequent it was not considered necessary to proceed further in this particular area of software development.

9.6 Conclusions

From the extensive experiments undertaken on the BBC microcomputer the following was concluded:-

1. The 'home computer' concept is viable provided that the software is available for:-

(a) Stored program control of external devices (EMBRI0).

(b) Data-Text transmission over a wide variety of public and private telecommunication networks (AMTEXT).

(c) Entertainment, educational, financial and work related functions.
2. The home computer market was born on the 'computer game' concept with simple keyboard input and visual display unit output via the domestic television receiver. Only a very small number of machines were used for other purposes within the home and entertainment, especially amongst the younger members of the family, was the greatest selling feature. Only after experimental evaluation did the full potential of such a machine become highlighted. Indeed the BBC 32k model B machine was probably the most versatile microcomputer on the market, in the mid 1980's, and the one most sought after by Educational Institutions for general purpose applications.

3. All programming for the project was undertaken in the BASIC language, not ideal, by an engineer who was not a professional programmer and without full information on the detailed architecture of the machine.

4. The real time background facilities (24 hours per day) provided by the home computer (i.e. meter reading, energy control, security etc) require the provision of interfaces both on the computer itself and on the external devices to be controlled and or read at specific times. Standards of interconnection would therefore be most important.

5. The need to optimise 'packet protocols' also becomes necessary in order to provide simple interconnection with public and private wide area networks (e.g. CCITT X25). This requires that the software developed for any machine must meet the required protocol standards to permit transmission over the requisite Wide Area Telecommunications Network(s). This implies that the appropriate communications protocol emulation program must be available for each machine considered.
6. The home computer and its potential applications, in the field of telematics, depends upon the many associated domestic items of entertainment, communication, household and energy optimisation. For example television receivers could well incorporate two way communications (i.e. interactive television), a home computer and interfaces for energy management and load control, but what market would there be for such a system? A manufacturer will only produce devices and systems if there is a large market for the particular product(s).

7. The feasibility of the system proposed in Chapter 8 was proven but the economics of implementation, from a point of remote metering and load control, is doubtful without co-ordination of both hardware and software standards on a large scale and the inclusion of suitable consumer incentive.
THE "AMTEXT" TEST BED

EXTERNAL CONTROL BBC COMPUTER INTERFACE UNIT
AMTEXT DATA STREAM SWITCH (DSX) UNIT

INTERNAL VIEW OF DSX SHOWING COMPONENT LAYOUT
Chapter 10

Integrating with the National Networks (MIDAS)

10.1 Introduction

In Chapter 9 the radio spectrum was utilised as the medium for communications between the 'home computer' and the utility database. In practice the major utilities in the UK share a fixed number of VHF radio telephone channels allocated on a national basis, which provide a means of communication with field mobiles.

If we consider the current, voice only, operations on these channels and the characteristics of voice messages together with time of day traffic patterns then it can be noticed that for much of the time the channels are idle.

By utilising packet techniques data transmissions over some, or all of, these channels would be possible and much greater channel efficiency would be achieved.

Such an application for a packet system is detailed in the MIDAS (Modular Integrated Data Acquisition System) proposals. The work undertaken in Chapter 9 serves as the basis for these proposals but the question of standards is addressed together with a modular approach to hardware development. Also radio networking with a pseudo LAN-WAN configuration is proposed although this may also be achieved, with the correct standards, via the proposed national digital services. The costs of implementation via either mode would need to be carefully assessed but the concept of true digital integration may be realised with both asynchronous and synchronous modes being employed within the networks.
10.2
Practical considerations of 'MIDAS'

10.2.1
Meter Reading

The Midas concept does not effectively replace the meter reader it provides him with direct access to the utility database and permits the meter reading to be input and the billing calculation to be performed EITHER on the remote utility mainframe (in mainframe time) or on the local computer unit used by the meter reader. The bill may then be handed to the customer or, at least, left at the premises for his/her attention. The important point here is that Midas does not replace the meter reader but it has a considerable effect upon the utilities computerised billing process as detailed in chapters 3 and 5.

10.2.2
Postage of Bills

With local printing of the customer's bills and the resulting direct delivery by the meter reader the cost of postage, at least for the initial bill, is removed.

10.2.3
Reduction of batch processing time on utility mainframes

With remote calculation (i.e. on site) of the customer's energy account(s) the need for the current transportation of written meter readings and the subsequent batch processing is removed.
10.2.4  
Need for additional interfaces to mainframes and other computerised systems

In order to optimise such a system interfacing to all the existing computer systems must be considered in terms of both hardware and software. The case of implementing such a system would depend upon the adopted standards both for the proposed Midas hardware and of the existing computer systems hardware. Also compatibility in software may be considered.

10.2.5  
The technical parameters for data transmission over VHF/UHF radio channels

Experiments conducted during the development of the Amtext system indicated that to optimise the throughput of information in the packet mode, a number of parameters must be considered in detail with regard to the overall optimum protocol for access to a VHF radio telephone network (see Chapter II).

10.2.6  
The utility Private Telecommunications Network (PTN)

In order to provide cost effective solutions to the information transfer requirements of a utility private telecommunications networks have been developed which provide comprehensive voice and data transmission facilities to meet the existing and projected future communications requirements of its customers and staff.
Such a network is illustrated in detail in Chapter II. The ability to incorporate such 'packet networks' as proposed in Midas is important and reinforces the arguments for standardisation and for employment of the Integrated Services Digital Network (ISDN) concept.

10.2.7
Midas over cellular radiotelephone systems

Cellular radiotelephone systems could likewise provide the radio medium for data transmission via suitable modems. The technical problems of Midas application over such networks may differ if conventional computer 'remote-terminal' access is anticipated (ie asymmetrical data flow). The optimisation of such proposed applications is analysed, in some detail, in Chapter II.

Essentially many of the problems which may be anticipated for the Midas system have already been considered in previous works and have been encountered in the Amtext experiments of Chapter 9.

With the advent of teleworking (or telecommunuting) the Midas concept provides a very useful, if specialist, application in this field and it should be noted that Midas was proposed by the author in 1986 and such systems (or system applications) are now being developed by the major U.K. Network Services providers i.e. British Telecomm and Mercury.
If the theory of 'Spot Pricing' is to be implemented (See Chapter 6) then it becomes necessary for effective telecommunications networks to be established between the electricity generating sources and the electricity sinks (i.e. the customers). In the case of industrial and commercial spot-pricing (see Chapter 6) it is essential that total stability be achieved within the overall telecommunications network(s) which are utilised for communicating the spot price. Effective real-time propagation of data through the system and the integrity of that data become most important as does the security of such data.

10.3 The Overall Telecommunications Network

In order to analyse a telecommunications network in terms of integrity, security and reliability we first need to examine the basic elements and techniques which form the network overall. If we combine Midas (or any packet based radio telephone data transmission network) with the in-house telecommunications network detailed in Chapter 11 then the basic elements we should consider breakdown as illustrated in Fig (10.1).

Essentially we have the VHF radio telephone system with packet data transmission as an 'add-on'. The digital information from Utility mobiles is input to a PCM link via a BS(Base Station) and a RNC(Radio Networking Controller) a microwave link acts as bearer. This is terminated via MTE's (Microwave Terminal Equipment) into a PSE(Packet Switch Exchange) and again routed via a land-line based PCM link to the remote mainframe computer site.
A BASIC DIGITAL NETWORK CONFIGURATION
FOR MIDAS IMPLEMENTATION

DIGITAL MICROWAVE LINK (EQUIV 30 CHANNEL P.C.M.)

MTE
RNC
BS

PACKET SWITCH EXCHANGE

UTILITY

MTE
PSE

64kb/s

PCM TERMINAL

30 CHANNEL P.C.M.

PCM TERMINAL

PSE

INTERFACE TO MAINFRAME COMPUTER

N.B. MTE  MICROWAVE TERMINAL EQUIPMENT
RNC  RADIO NETWORKING CONTROLLER
BS  VHF BASE STATION
PCM  PULSE CODE MODULATION

Fig 10.1
The integrity, security, reliability and resilience of the overall telecommunications network is considered in detail in chapter 11.
CHAPTER 11

INTEGRITY, SECURITY, RELIABILITY AND RESILIENCE

11.1 Introduction

First I shall define the above terms in the context of this work.

**Integrity:** The state of being entire and correct; referring to the transmission of data in its entire and correct form through a telecommunications system or network from source to destination.

**Security:** The state of being safe and free from corruption; referring to the safe and secure transmission of data through a telecommunications system or network from source to destination.

**Reliability:** The state of being reliable; referring to the reliable transmission of data through a telecommunications system or network from source to destination.

**Resilience:** The level of availability under fault conditions.

In order to ensure that the data being sent over a telecommunications network is 'entire and correct' it becomes necessary to consider error control.

11.2 Error Control

An error in the transmission of data implies that one or more bits have been received incorrectly (i.e. a binary '0' has been received as a binary '1' and vice versa) or with omissions (i.e. where bits have been lost as a result of frame synchronisation distortion or noise bursts).
The systems which have been considered for both the purpose of remote metering and load control involve a frame or packet type data transmission architecture and their subsequent transmission over radio telephone based systems and composite telecommunications networks.

The overall data communications link is subject to two basic error patterns.

11.2.1 Isolated errors or short bursts of errors attributable to general interference such as noise and multipath propagation which creates fading effects. It should be noted that during the 'Amtext' experiments VHF (145Mhz) and HF (3.5Mhz) frequencies were examined. The VHF configuration employed FM modulation with quieting figures of (carrier to interference ratios) 20dB and it is these VHF channels which are considered here. No direct experiments were conducted with regard to fading, as experienced if the data terminal is housed in a vehicle, but the average fade rate and the fade periods are related to the vehicle speed. Other experiments indicate that the fade period, for most practical purposes, would be in the region of 1-10ms.

11.2.2 Relatively long bursts of errors (again in the mobile case) due to temporary loss of signal in urban areas (i.e. when shielded by tall buildings etc). These breaks can have any value but may result in a 'time-out' if they exceed certain link control parameters.

Theory suggests that type 11.2.1 errors may be minimised by forward error correction (FEC). However, type 11.2.2 errors are totally unpredictable and automatic re-transmission on request (ARQ) techniques need to be applied.
Experimental results gathered during AMTEXT system field trials, conducted over VHF channels, including mobile trials, suggest that errors of type 11.2.1 occur at an average rate of approximately 4/100 blocks transmitted and in response to these errors a block code technique was simulated for their detection.

11.3.1 Burst errors can be effectively detected by a number of techniques providing that their duration or burst period is known. This was generally not the case with the VHF experiments. In the stationary case they were found to be relatively infrequent and of variable duration, in the mobile case they were found to be relatively frequent and again of variable duration. This effect would be magnified in a multi-broadcast network e.g. a cellular system. (N.B. register block analysis used in AMTEXT experiments to verify burst error parameters).

To overcome the problems of burst errors a distributing technique was investigated which distributed check characters within the data blocks. The technique, which requires true implementation on a second processor, would enhance detection of these burst type errors.

11.3.2 Block construction and code distribution

Essentially the problem of synchronization of the code blocks and the error check character distribution patterns poses problems of throughput delay. A dense distribution pattern gives increased protection in long packets of data but would produce unacceptable overheads in terms of throughput delay. Also the type of application has to be considered i.e. some applications require only short packets of data with consequent short delay parameters whilst others carry large data blocks such as in the case of file transfer applications.
Taking the above into account to optimise such a system suggests that a block format permitting a variable density of check characters might optimise error detection for all cases i.e. long and short data packets. The density for a particular application being decided at the transmitter data buffers. Experiments conducted with the 6502 microprocessor gave the results as shown in Table (T 11.1).

Table (T11.1) shows sync type, data block size and error check character density (ECCD) against efficiency. Although the tests were 'bench simulations' it can be clearly seen that, for an almost constant ECCD, the data block efficiency increases in proportion to block size.

The longest data block has an efficiency of approximately 55% with an information rate of 1200 bits/sec and will be received intact even if 10% of the packets require re-transmission. It should be noted that the sync patterns, which indicate the error check character density, may be optimised to prevent data being mistaken for a sync pattern. Also a high probability of sync in the presence of errors is an important feature of the sync patterns characteristics and would require further detailed study to optimise the design. As an example if a sync pattern of 4.8 bits is utilised then a maximum of 8 errors can be tolerated in the received sync. The probability of a random data stream being mistaken for one of 8 sync patterns is 9.1 x 10⁻⁶ and the probability of sync being received correctly with a random error rate of 2% is 99.96%. However, the sync is not protected by the error check character technique therefore, when 'bursts' of errors occur, the sync performance falls off. Experiments conducted with sync patterns suggest that bursts of errors lasting about 7ms, with a quieting figure of 18dB (i.e. carrier to noise ratio) and a receiver threshold of 3dB the sync success rate for the worst case vehicle speed will be approximately 93%.
### TABLE (T11.1) ERROR CHECK CHARACTER DENSITY

<table>
<thead>
<tr>
<th>SYNC NO.</th>
<th>ERROR CHECK CHAR. DENSITY</th>
<th>CH. CHAR. IN INFO. FIELD</th>
<th>TOTAL CHARs. IN INFO FIELD</th>
<th>EFF.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25:1</td>
<td>2</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>20:1</td>
<td>2</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>15:1</td>
<td>3</td>
<td>45</td>
<td>60</td>
</tr>
</tbody>
</table>

### TABLE (T11.2)

<table>
<thead>
<tr>
<th>PHYSICAL CONDITIONS</th>
<th>Percentage block errors (after FEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,400 band channel 512 data bits</td>
</tr>
<tr>
<td></td>
<td>150 band channel 32 data bits</td>
</tr>
<tr>
<td>Speed (km/hr)</td>
<td>Signal Strength (dBm)</td>
</tr>
<tr>
<td></td>
<td>no FEC</td>
</tr>
<tr>
<td>0-20</td>
<td>-120 to -110</td>
</tr>
<tr>
<td>0-20</td>
<td>-110 to -100</td>
</tr>
<tr>
<td>0-20</td>
<td>-100 to 90</td>
</tr>
<tr>
<td>0-20</td>
<td>-90 to 80</td>
</tr>
<tr>
<td>20-40</td>
<td>-120 to -110</td>
</tr>
<tr>
<td>20-40</td>
<td>-110 to -100</td>
</tr>
<tr>
<td>20-40</td>
<td>-100 to 90</td>
</tr>
<tr>
<td>20-40</td>
<td>-90 to 80</td>
</tr>
<tr>
<td>40-75</td>
<td>-120 to -110</td>
</tr>
<tr>
<td>40-75</td>
<td>-110 to -100</td>
</tr>
<tr>
<td>40-75</td>
<td>-100 to 90</td>
</tr>
<tr>
<td>40-75</td>
<td>-90 to 80</td>
</tr>
</tbody>
</table>
An example of the modified frame format is shown in Figure (11.1) and is compared with the standard High Level Data Link Controller (HDLC) standard format.

Table 11.2 shows a summary of field trial results obtained over a cellular radio network using similar modified HDLC formats as previously described. These results were obtained during the development, by Racal, of a Cellular Data Link Control (CDLC) standard.

Such integrity enhancement techniques may be applied at any stage of a transmission network but it should be remembered that the price of increasing throughput over, for example, a VHF radio network may lead to problems of standardisation when interconnection with other data networks is contemplated (i.e. PSS with X25 protocol). The reduction in errors obtained over the radio path(s) may well be off-set by the need for expensive standards conversion(s) at other points in the overall telecommunications transmission network giving rise to yet more throughput delays.

In general it may be noted that Cyclic Polynomial Techniques (CPT) and in particular Cyclic Redundancy Codes (CRC) are amongst some of the most powerful error detecting codes in current use. Cyclic coding involves a calculation at the transmitting station in which the block of data to be sent is treated as a pure binary number and is then divided by a pre-determined number defined by a polynomial expression. This produces a remainder which forms the check digits which are then transmitted at the end of the data block. At the receiving end the terminal repeats the division using the same pre-determined number and dividing it into the received data including the check digits.
ENHANCING ERROR DETECTION / CORRECTION VIA MODIFIED H.D.L.C. FRAME FORMAT

The information frame

<table>
<thead>
<tr>
<th>Bit - Nr</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>0</td>
<td>SZ</td>
<td>P/F</td>
<td>EZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR = RECEIVE</td>
<td>0</td>
<td>SZ</td>
<td>P/F</td>
<td>EZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>READY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REJ = REJECT</td>
<td>0</td>
<td>SZ</td>
<td>P/F</td>
<td>EZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where:
- **FLAG** = flag sequence
- **ADDRESS** = station address field
- **CONTROL** = control
- **INFORMATION** = INFORMATION FIELD
- **FCS** = frame check sequence

The fixed frame format

Modified frame format

SYNC pattern variable based on fixed number of bits e.g. 48.
If no errors have occurred during transmission the division will produce no reminder. Increased complexity of the cyclic code gives powerful detection but also greater redundancy with each block transmitted. The optimum codes are a compromise between good burst error detection and low redundancy. This process is illustrated in Table (T11.3) and a suitable software listing for CRC routines is detailed in Table (T11.4).
**Table (T11.3) CRC Division Process.**

<table>
<thead>
<tr>
<th>Data</th>
<th>1 1 1 0 0 1 0 1 1 0 1 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisor (d)</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

**Quotient**

<table>
<thead>
<tr>
<th>(a 1 at every d)</th>
<th>1 1 1 0 1 0 1 1 0 1 1 0 0 0 0 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 1 0 0 1 0 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 0 1 1 1 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 1 0 1 0 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 0 0 1 1 1 1 1 0 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 1 0 1 1 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ex-or</th>
<th>0 0 0 1 0 1 0 0 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>1 0 1 0 1 1</td>
</tr>
</tbody>
</table>

| Ex-or (remainder) | 0 0 0 0 1 1 |

**1st bit** 1 1 1 0 0 1 0 1 1 0 1 1 0 0 0 1 1 **last bit**

Data plus remainder, transmitted to left

| :  | As above |
| :  | :       |

| : | No error 0 0 0 0 0 0 |

---

**Table (T11.4) CRC Program Listing re 6502**

<table>
<thead>
<tr>
<th>0001</th>
</tr>
</thead>
<tbody>
<tr>
<td>0002</td>
</tr>
<tr>
<td>0003</td>
</tr>
<tr>
<td>0004</td>
</tr>
<tr>
<td>0005</td>
</tr>
<tr>
<td>0080</td>
</tr>
<tr>
<td>0081</td>
</tr>
<tr>
<td>0082</td>
</tr>
<tr>
<td>0083</td>
</tr>
<tr>
<td>0084</td>
</tr>
<tr>
<td>0012</td>
</tr>
<tr>
<td>0013</td>
</tr>
<tr>
<td>2010</td>
</tr>
<tr>
<td>2010</td>
</tr>
<tr>
<td>2010</td>
</tr>
<tr>
<td>2010</td>
</tr>
<tr>
<td>2012</td>
</tr>
<tr>
<td>2014</td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td>2019</td>
</tr>
<tr>
<td>2018</td>
</tr>
<tr>
<td>201C</td>
</tr>
<tr>
<td>201D</td>
</tr>
<tr>
<td>2020</td>
</tr>
<tr>
<td>2022</td>
</tr>
<tr>
<td>2024</td>
</tr>
<tr>
<td>2026</td>
</tr>
<tr>
<td>2028</td>
</tr>
<tr>
<td>2029</td>
</tr>
<tr>
<td>202A</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
</tbody>
</table>

**Symbols:**

2010 CRC1 0080 DATA 0083 POLYLS 0084 POLYMS 0081 REMLS 0082 REMS

No error(s) detected
6290 bytes free
11.5
Network Resilience

11.5.1
Introduction

Norweb's area of supply is shown in Fig.11.2. The four southern areas of Mid Lancashire, South Lancashire, Manchester and Peak are essentially urban areas whereas Lakeland, which encompasses the counties of Cumbria and the northern part of Lancashire, is essentially rural. Each Area has a major Commercial, Administrative and Engineering Centre, or Node, which acts as a focal point for communications between Board Headquarters (located in the City of Manchester), the Computer Centre (also located in Manchester) and the respective Zone Engineering Centres, Depots, Showrooms and Substations. Each Area is equipped with an electronic digital switch Private Automatic Branch Exchange (PABX) operating under stored program control which provides both internal and national telephone communications. These exchanges are equipped with Automatic Call Distribution (ACD) facilities which, via a Customer Service Bureau (CSB) and a Customer Accounts Bureau (CAB), provide the major telephone interface between the Board's customers and staff.

The Area Node also provides a focal point for remote control, indication, alarms and telemetry (Telecontrol) on the electricity transmission (132/33kV) and distribution (11kV) networks during normal working hours. Out of normal hours operation of these systems may be transferred, together with (CSB) facilities, to the Norweb Transmission Control and Reporting Centres (NTCC and NRC) located in Manchester. These systems are all computer based (GEC 4065 series) and all communications facilities are, similarly, provided via the Norweb Private Telecommunications Network.

The network may be divided into two basic elements or components:-
THE NORTH WESTERN ELECTRICITY BOARD
(NORWEB)

Fig 11.2
1. NODES Consisting of transmission, control, signalling and
switching equipment such as digital telephone exchanges,
local area networks, multiplexers etc. These devices are
all software configured and illustrated in Fig. 11.3.

2. LINKS Consisting of metallic conductors, microwave radio
(or channels, optical fibres etc.
bearer
circuits)

These two elements combined (i.e. the network) are illustrated in
Fig. 11.4.

11.5.2 The need for Resilience

As can be seen, with reference to Fig.11.4, the total data and
telephone communications systems utilised within Norweb rely on the
network being fully available and, if it is to be cost effective,
being fully utilised at all times.

The usefulness of a system is a function of the time it is available
for use relative to the time when it is required for use.
Availability may be quantified for individual components, systems or
complete networks from the expression:-

Availability (A) = \[ \frac{MTBF}{MTBF + MTTR} \] \hspace{1cm} (1)

and for a network with \( n \) series components

Network Availability \( (N_{Asc}) = A_1 \times A_2 \times A_3 \times A_4 \cdots \times A_n \) \hspace{1cm} (2)

Similarly for a network with \( m \) parallel components

Network Availability \( (N_{Ap}) = 1 - [(1-A_1) \times (1 - A_2) \times \cdots (1 - A_m)] \) \hspace{1cm} (3)
**TYPICAL HARDWARE INTERCONNECTIONS AVAILABLE AT AN AREA NODE**

- TO COMPUTER CENTRE, HQ AND OTHER AREAS
- CUSTOMER SERVICE BUREAU
- EXTERNAL TELEPHONY VIA BRITISH TELECOM
- NORWEB NETWORK 2 MBPS
- INTERNAL TELEPHONY
- A C D
- ENG. OFFICE OR SHOWROOM
- 64 KBPS
- MUX
- TELECONTROL
- 64 KBPS
- TER M IN A L CLUSTERS
- LOCAL AREA NETWORK
- DISTRIBUTED COMPUTER(S)
- CONNECTION OF OTHER DEVICES E.G.: MICRO, WORD PROCESSORS, TELEX, GRAPHICS.
- (INSERT PAD AS REQUIRED)
- LEASED LINE OR VIA BRITISH TELECOM PSS TO COMPUTER CENTRE, HQ AND OTHER AREAS

Fig 11.3
First generation digital links (24CH PCM)
Second generation digital links (30CH PCM)
Digital microwave link (30/120CH PCM)
Analogue microwave link (36CH FDM)
Under development
● Zone or Engineering Offices

NORWEB PRIVATE TELECOMMUNICATIONS NETWORK 1988
It follows from (2) and (3) above that by selective duplication of the most vulnerable components in the network it is possible to achieve improved protection against total network failure without necessarily having to duplicate the whole network.

As a network is composed of combinations of nodes and transmission links historical performance data on both nodal hardware and the transmission links utilised may also serve to predict the network availability (NA) which may be achieved under any given hardware or link failure condition(s).

This network evaluation parameter, termed 'Network Resilience', may be defined as the Network Availability under estimated worst probable fault conditions.

It follows therefore that

\[
\text{Estimated Network Resilience (ENR)} = \text{Network Availability (NA)} \times (WPFCF) \tag{4}
\]

where WPFCF = Worst Probable Fault Condition Factor

It follows that the estimation or prediction of the WPFCF has great impact on the network resilience and relies, to a large extent, on the detailed study of a wide range of historical data ranging from link performance statistics to local weather patterns, frequency of electrical storms, patterns and frequency of cable damage and geographical location of network nodes.

As a network develops, over a period of time, the elements which compose the network (i.e. nodes and links) tend to be fairly standard, or at least only a generation apart. Performance data which applies to one element of the network usually applies to many other elements of the network thus predicting network resilience and its effects on network development and hence cost is not as daunting a task as it may first appear.
11.5.3 Implementing Network Resilience

With reference to Fig. 11.4, Norweb's private telecommunications network comprises a digital binary star topology supplemented by an analogue ring network. It is designed to cater for a WPFC factor of 0.5 giving an ENR figure of approximately 0.49. This implies a minimum service level, under worst predictable fault conditions, of nearly 50% and applies to both data and telephony traffic on the network.

Typical hardware interconnections, available at an Area node are illustrated in Fig. 11.3 and are designed to optimise resilience from a hardware standpoint. Cascade multiplexing from the main digital highways provides for full cross patching at the local terminal cluster level and at the on-going, lower order network, modem levels.

Protocol translation is provided, where necessary (ICL based CO3/X25) and Local Area Network (LAN) facilities provide for a wide range of intelligent resources to be shared both locally and remotely via the Packet Switch Exchange (PSE) and, if necessary, via the UK Wide Area Network (WAN) known as Packet Switch Stream (British Telecom PSS).

11.5.4 Maintaining Resilience

As a private network develops, design concepts which embody the network resilience approach may be utilised to predict and assess minimum network performance levels. However, the accuracy of such predictions will be related directly to the amount of statistical performance data that has been obtained from the network during its evolution. This, in turn, implies a strong case for the employment of network management systems as early as possible in the development of the network.

Furthermore it becomes necessary to consider the quality and reliability of the private and associated national networks during periods of switched inter-connection (e.g. telephone communications.
between parties on the private and public networks; data communications between terminals on the private and public packet switch networks) when estimating the overall switched network resilience (OSNR). Although little can be done perhaps, in a technical sense, about public networks commercial pressure can be brought to bear on the public network companies to improve services.

This again reinforces the case for the employment of network management systems particularly to confirm public switched network call charges and, in the case of data networks, (e.g. packet switch networks) the throughput of data compared with the actual data sent. Most public packet switched network providers charge for all packets input to their network irrespective of how many retries are necessary before the packet is received correctly at the distant terminal device. The number of retries may be due to corrupted packets or an overloaded network. However, without a network management system to monitor and record events the overall network performance, and hence cost, cannot be accurately assessed.

11.6 Conclusions

Resilience may be defined as "the power of resuming the original form after compression". Private telecommunications networks which are fully utilised require resilience and the worst probable fault condition factor (WPFF) is an approach to quantifying resilience and predicting a minimum guaranteed level of service for a given network. The accuracy of prediction relies heavily on historical performance data for the network gathered during its evolution or from similar networks and implies a strong case for the early employment of network management systems.
CHAPTER 12

THE OUTLOOK FOR IMPLEMENTATION AND FURTHER RESEARCH

12.1 The Initial Objective

The objective of this thesis may be summarised as follows:

To investigate remote electricity metering and load control in terms of the now available UK ESI private and national telecommunication networks, the intelligent building, the home computer and domestic energy management concepts.

12.2 Conclusions

The following areas have been investigated; the current telecommunications networks which may be utilised (Chapters 1 and 2); the current meter reading and customer billing processes (Chapter 3); remote meter reading concepts (Chapter 4); ESI - consumer billing interface (Chapter 5); load control (Chapter 6); current remote meter reading field trials (Chapter 7); the Intelligent Home and the Area Board Data Base (Chapter 8); text, communications and control on the BBC microcomputer AMTEXT (Chapter 9); integrating with the National Networks MIDAS (Chapter 10); network integrity, security and reliability (Chapter 11).

The ESI telecommunications networks vary widely from Area Board to Area Board with CEGB regions remaining fairly consistent (at least in policy if not in practice) throughout the UK. Digital techniques are widely employed for the provision of both speech and data communications and the ESI is granted permission "to run telecommunication systems" under Section 7 of the Telecommunications Act 1984. However, to-date, the ESI may generally only communicate with its customers via the Public Telecommunications Operators (PTO's) i.e. British Telecom and or Mercury Communications. However, a report, issued by the Rural Telecommunications Commission, suggests that other private operators, with established networks, having surplus capacity,
capable of providing telecommunications services to third parties, should be considered, where possible, as an alternative to the present duopoly within rural areas of the UK. Currently at least one Area Board (NORWEB plc) are investigating the feasibility of such an undertaking which might provide a lead into total integrated communications (i.e., customers premises to electricity distribution company) for remote metering and load control. It is worth bearing in mind that the Department of Trade and Industry (DTI) commissioned a report in 1973 which concluded that remote meter reading might be economically viable in rural areas where transport overheads are very high. If such overheads can be removed by utilising telecommunications techniques for remote metering and other associated rural telecommunications services from a common utility network provider, then even greater savings might accrue for both the utility companies and their customers.

The ESI has extensive radiotelephone networks throughout the UK which were primarily designed for analogue speech communications. Stored program control coupled with cellular radio techniques now permits both speech and data transmission over such networks and, as illustrated, in the AMTEXT experiments (detailed in Chapter 9), the idle time over such networks might easily be used for remote metering, energy management and load control applications. However such applications would similarly be subject to licensing approval by the DTI and regional agreements between customers and the supply company. The nature of the electricity transmission and distribution networks with the widespread geographic location of substations, transforming and switching points also provides great potential for cellular radiotelephone and very short range "cordless telephone" applications with system hardware being centred at points where an electricity supply, housing facilities, telecommunications and easy aerial installation may all be provided.
The intelligent home, office and or building concept is fast gaining acceptability, as an example, on the domestic front the cost of central home computing capable of providing AMTEXT type facilities together with a wide range of security, energy management and on-line computer applications represents only 2% of the overall cost of a new home (based on a house price of £100,000). If this is coupled with telecommuting (see Chapter 8) and the cost of the computer system is borne by an employer or business interest then very great savings may be accrued overall as the computer operating in background mode, provides home energy management, entertainment, security, meter reading and load control facilities together with business applications being provided in the foreground mode both on and off line as required.

The savings in transport, office accommodation and fuel costs far outweigh the additional on-line telecommunications costs. As an example Rank Xerox discovered that the associated costs of employment in Central London amounted to no less than three times the employee's salary. Similarly the DTI and IT World, through the 'Remote Work Unit Project', has highlighted how disabled people are now able to work effectively, from home, by employing telecommuting techniques.

Relatively high speed data transmission over single phase AC mains is now viable and packages are now available from at least one major UK supplier and promise to be most useful for systems where the cost of separate data or telecommunications wiring is prohibitive. Data rates of up to 4800 baud are quoted with automatic reduction of transmission rates on noisy routes. At present there are no UK standards for mainsborne systems and the development of such standards, and indeed comprehensive mainsborne systems, is of particular interest to heating, air conditioning and energy management system providers. As a result of the early work on AMTEXT at least one UK company has kindly offered to provide facilities for further research in the
field of mainsborne signalling for energy management systems and detailed work in this field has been located which, coupled with current 'chip-set' technology, suggests cost effective mainsborne communication at transmission rates well in excess of 1 MHz. Digital transmission, via the electricity mains would provide one of the most cost effective means of widespread terrestrial telecommunications, utilising existing electricity mains cables laid over the last 150 years, to every premises with electricity supplies (i.e. in the case of the UK almost every habited dwelling).

As the national requirement for telecommunications services continues to increase this option becomes increasingly attractive to the Utilities.

The concept of the stand-alone dial-up idle line working for remote metering, on a domestic basis, has a number of inherent problems and the choice of access protocol becomes most important. In the domestic environment automatic metering devices using the domestic telephone line as the communications media must share this resource with other users and possibly other automatic devices within the home. Each of the 'other users' has a particular traffic pattern and the use of the domestic telephone circuits for computer, remote control, energy management and auto-dial alarm devices is also on the increase therefore the overall effective idle-line periods are reducing. A satisfactory protocol must be easy to implement and flexible enough to allow new meters to be added to the system without difficulty.

A meter unit may have a limited supply of power therefore the number of call attempts per successful call should be minimised. Also in the case of a fault on the local telephone circuit, PSTN or utility company system, a backlog of calls will be generated and for this reason it is necessary to ensure that the number of such calls is minimised. To date there has been no widespread adoption of such systems (i.e. CALMU) by utilities in the UK.
A mathematical analysis of two possible approaches to protocol development are detailed in Chapter 11 and an approach to idle time radiotelephone networking is outlined in Chapter 10.

The generation of electricity increases in finite steps (i.e. a 10 MW generating plant is designed to provide maximum overall efficiency at a full load of 10 MW) and if generating and transmission costs are to be minimised, a constant matching of overall generating capacity to overall load requirement is essential. In order to utilise the spot pricing theory, developed in the USA and detailed in Chapter 6, surplus capacity requires to be taken up by offering special time of day rate tariff incentives to customers. Thus an equalisation, between the load demand and generating capacity, is maintained at any particular instant in time.

For this situation to be truly optimised the equalisation shall hold for all instants in time, no matter how small, and this in turn suggests the need for a feedback element between generation, transmission and consumption (i.e. between the utility supply/generation companies and their customers) capable of transmitting the spot energy prices at both high speed and with regional or national coverage.

As demand increases price would correspondingly increase and therefore the element introducing negative feedback (i.e. stability) into the electricity generation, transmission and consumption equation is a factor related directly to the spot price of electrical energy. The media for transmitting such elements of information is the ESI (private) and public telecommunications networks integrated to provide a highway for pricing information which may be varied to either stimulate or depress the consumption of electrical energy. Spot pricing theory is considered, in some detail, in Chapter 6 together with other related parameters which affect the optimisation of electricity generation and consumption. However,
stability is fundamental to such optimisation and therefore the integrity, security and reliability of electricity transmission and distribution networks, together with their associated telecommunications networks (i.e. providing pricing information to and remote metering and billing information from the utility companies customers) should be considered in relation to spot-pricing. A failure or error in pricing information could easily result in load shedding, instability and loss of electricity supplies (i.e. positive feedback) to large numbers of customers. With this in mind some primary considerations with regard to implementing telecommunications network resilience are detailed in Chapter 11 with particular reference to NORWEB's comprehensive private digital telecommunications network.

12.3 Areas for Further Research

During the course of this work the following potential areas for further research became apparent:-

(1) The intelligent building and the reading of electricity meters and computation of the electricity bill at the customer's premises with payment via on-line electronic fund transfer. This area of work has close association with telecommuting, telemarketing and electronic fund transfer.

(2) The transmission of high speed digital signals over the electricity mains. This area of work has close association with the intelligent building, energy management and load control. It is of particular interest to a number of manufacturers of energy management systems for the utilisation of existing mains wiring for transducer communication and control and implies vast savings in labour costs particularly in the refurbishment of multistorey complexes.
(3) The cellular radio concept and the utilisation of idle-time working for background data transmission. This area of work has close association with distribution network telecontrol, energy management and load control.

(4) The utilisation of surplus capacity on private telecommunication networks for third party traffic. This area of work has close association with national telecommunications regulatory affairs.

(5) Time of day electricity tariffs, spot pricing and the influence of finite security and reliability on such systems. This area of work has close association with public telecommunications network traffic analysis, performance and disaster recovery. The integration of both electricity distribution and telecommunications networks for the purpose of the supply, control and price optimisation of electrical energy is one which might benefit by detailed computer simulation studies.
GLOSSARY

The more fundamental and widely used terms are detailed here, the remainder are introduced as they arise in the text.

Utilities

Collective term which describes the organisations, bodies or undertakings whose main responsibility is for the supply and distribution of commodities or services which are generally recognised as essential, e.g. electricity, water and gas. The responsibility for electricity and gas distribution is vested in the respected Area Boards whilst water is currently distributed by a much wider number of Authorities.

Consumer

A member of the public who accepts responsibility for payment for the use of a commodity by the members of the respective household.

Household

The census definition (employed here) relates to a group of people living together and benefitting from common housekeeping.

Dwelling

A set of contiguous rooms, with separate access, which provide a living area for the members of one or more households and consumers.

N.B. As there are certain differences in official figures for dwellings, households and consumers, it is assumed that the number of dwellings is equal to the number of households.
**Meter**

A device able to measure the consumption of a commodity. With reference to manual reading systems it must be able to provide summation of the consumption over a given period of time and also store and display this information.

**Address**

A necessary feature of all meter reading systems such that each meter and such reading(s) can be precisely identified and used for consumer billing and other purposes. It is a pre-requisite therefore that each meter, including the appointed dials and register, must have a unique address.

**Network**

Any system that represents a series of points and their interconnections. A 'Telecommunications Network' is a system that represents a series of data channels or highways interconnecting telecommunications, computer terminal or peripheral equipment.

**Network Architectures**

These comprise the body of rules specifying how the supplier's products can be connected together and their physical and functional relationships. The 'architectures' also specify the various communications protocols to be used. These may conform to international standards or may be the supplier's own version.
Local Area Networks (LANs)

These systems are specifically designed for the interconnection of computer systems and terminals within a single geographical site. These systems are further characterised by wide bandwidth, i.e. 10 Mbit/s and above.

Wide Area Networks (WANs)

The systems are very large, possibly global (i.e. P.S.T.N.) switched networks, capable of supporting voice, data and or video information.

Telesoftware

Software transmitted by broadcast or line to Teletext or Videotext terminals with added processing capability. After reception allows interactive computation without further communication.

Teletext

Broadcast text and graphics system utilising spare lines of TV frame. A limited number of pages are transmitted on a cyclical basis, received and displayed by domestic TV with decode and display circuitry.

Videotext

Description used by CCITT* for an interactive information retrieval service operating through the public switched telephone network. Capable of text or graphics. This term described what is known in the UK as Viewdata with British Telecommunications proprietary name Prestel.

(* see overleaf)
CCITT

Committee Consultatif Internationale Telephonique et Telegraphique. The international body responsible for deriving technical standards and codes of practice for telephone and telegraph transmission networks and systems.

ISO

International Standards Organisation which has described a seven layer model which if followed will permit any device to interwork with any other device. This is usually referred to as the Open Systems Interconnection (OSI) 7 - layer model.

ESI

A collective terms used to describe all the various bodies of the Electricity Supply Industry within the United Kingdom (e.g. Central Electricity Generating Board, Area Boards and Electricity Council).

Telematics

An anglicised version of the French 'Telematique' applied to the combination of automatic control and telecommunications. Telematics involves the convergence of voice and data communication, together with computers and office automation, into an integrated approach to information technology.
**Integrated Services Digital Network (ISDN)**

An integrated digital network (IDN) used for more than one service, e.g. telephony and data. In the present British telecommunications networks there are a number of discrete networks, e.g. Telex, Packet Switching Service. Economic benefits can accrue to network providers and users if these networks were combined into one large 'Integrated Services Digital Network'.

**HDLC**

A High-level Data Link Control protocol framing technique responsible for sending error free data over the physical channel connected between two points and detailed in 'layer 2', the link layer, of the OSI 7 Layer Model.

**OUTAGE**

A disconnection of a section of an electricity transmission or distribution network in order to permit work to be undertaken on the de-energised section or a disconnection of a section of network due to a fault condition which results in the de-energising of a section of the electricity transmission or distribution network. Transmission voltage levels are 33kv and higher, distribution voltage levels are 11kv and below.

**dBm**

The power level, expressed in decibels, compared with a reference power level of 1 mW.

Eng.105/A/1.138 - 1.143
APPENDIX 1

Software Specification

Title: A M T E X T PSI (Packet Simulation 1)

Storage: Tape Cassette or Disc

Language: BBC Basic and 6502 assembler

User facilities: (a) Plain language text for transmission to be input via the keyboard and stored in an array prior to transmission.

(b) Plain language received text to be output on VDU or VDU and printer as defined by user in response to screen prompt.

(c) Pre-assembled plain language text to be transmitted in response to screen prompt.

(d) Automatic repeat transmission of message text until acknowledgement received from recipient station.

(e) Two basic receive modes GENERAL and SPECIFIC, i.e. in the GENERAL mode all messages received are output to the user whilst in the SPECIFIC mode only messages addressed to the user are output and automatically acknowledged.

(f) Transmission speeds of 300 or 1200 baud may be selected.

(g) Timeout on corrupted messages after 100 secs, reset by ESCAPE key.
(h) Maximum message duration 100 secs.

(i) Error check on received ASCII characters.

(j) Message packet timing protocol illustrated in Fig. 7.

(k) Station identification check in-built for SPECIFIC mode working.

(l) All message packets commence with a sync character.

(m) All message text ends with an end of text character.

(n) Call sign header automatically prefixed to all messages e.g. GØXXX de G3YYY.

(o) Sign off automatically appended to all messages e.g. 73s de G3YYY.

(p) Data carrier detected in receive mode is under interrupt working via assembler routine.

(q) Normal text line edit facilities to be available to the user during text input routine.

(r) Printout of text for transmission to be provided on reply to screen prompt, prior to transmission, if requested by user.
(s) VDU screen background colour variation to be provided with mode selection i.e. red for text input and TX modes, blue for menu and RX modes.

(t) Program structure to provide for auto message transmission as UK licensing permits.

(u) All message data input/output to be via the cassette port in straight ASCII modulated onto 2400/1200HZ audio tones (i.e. a.f.s.k. modulation).

(v) Auto receive mode reset following corrupted or false data.

(w) MCW identification may be appended to each message packet, if required, under licence regulations.
APPENDIX 1 (cont'd)  AMTEXT - Program Listing

10 REM G3WRI 'AMTEXT' PROTOCOL 1 with selectable MCW identification, 300/1200 baud TX/RX, LISTEN before TRANSMIT and ACKNOWLEDGE facilities.

20 REM This is version 'PACKET-5' providing RS423 to Cassette Port I/O with Message Addressing, Timeout Trap, Repeat Transmit and Printout facilities.

30 DIM #10: T=0; P=0; C=0; A=0; D=0
40 #TV255
50 E=0
60 FD='y'; FS='n'; LS='th'; HS='tm'
70 #FX 15, 0
80 #FX 16, 0
90 MODE 3: VDU19, 0, 4, 0, 0, 0
100 DIM GAPZ 40
110 FOR ASP=0 TO 2 STEP 2
120 Z=6APZ / OPT
130 .RSIN CMP £7
140 .BIFF PHA
150 .BIFF PHA
160 TI A
170 AND E2
180 BEQ MODE
190 STA &80
200 .MODE PLA
210 RTS
220 J
230 NEXT RSPX
240 RT: IF R=32 THEN 410 ELSE 400
250 PRINT: IF R=6 THEN 410 ELSE 410
260 VDU19, 0, 4, 0, 0, 0: INPUT "TO CONTINUE please INPUT YOUR CALL SIGN ', CAL$ "
270 VDU19, 0, 4, 0, 0, 0: VDU3: INPUT "To select TRANSMISSION SPEED ...INPUT 'TH' for 300 baud or 'TM' for 1200 baud ',' . " SPO
280 INPUT "Do you wish to append each MESSAGE PACKET with your CALL-SIGN in MCW? (Y/N) ", MCW$
290 IF MCW$: T$ THEN 470 ELSE 460
300 IF MCW$: P$ THEN 470 ELSE 440
310 INPUT "Set LISTENING PERIOD (in centi-seconds 100 to 3500 ) prior to COMMENCING TRANSMISSION of message packet", E
320 IF E<100 OR E>3500 THEN 470
330 VDU19, 0, 4, 0, 0, 0: VDU3: PRINT "Do you wish to TX or RX? Enter T for TX or R for RX."
340 IF R=84 THEN 520
188(i)

510 IF R=82 THEN 1270 ELSE 580
520 PRINT**"System in TI MODE."
530 ON ERROR GOTO 2360
540 VDU19,0,1,0,0,0
550 INPUT**"Please enter CALL SIGN of RECIPIENT STATION ",ADD$
560 INPUT**"Please enter approximate No. of LINES OF TEXT TO BE TRANSMITTED "H
570 INTR**"Please enter TEXT TO BE TRANSMITTED. Each new line commences with a prompt(?)"
580 FOR I=ITOH
590 IF I<10 THEN PRINT TAB(1);I;
600 IF I=10 THEN PRINT I;
610 IF I>10 THEN PRINT I;
620 INPUT LINE #():NEXT
630 INPUT**"Do you require a PRINTOUT of the TEIT to be transmitted? (Y/N)" ,TTS$
640 IF TTS$:T$ THEN 660
650 IF ITS$:P$ THEN 720 ELSE 630
660 PRINT**"TURN PRINTER ON" :VDU2
670 PRINT**"TRANSMITTED message reads as follows:""
680 PRINT ADD$: "de "CAL$;
690 FOR I=ITOH:PRINT**:A$(I):NEXT
700 PRINT** 73s "de "CAL$;
710 PRINT**"TRANSMITTED message ENDS." :VDU3
720 PRINT**"Press 'RETURN' to TRANSMIT.""
730 R=GET:IF R=13 THEN 740 ELSE 730
740 C=5
750 GOTO 1400
760 *FX 138,1,1
770 *FX 2,2
780 *FX 205,64
790 IF SPD$=H$ THEN 830
800 *FX 7,3
810 *FX 8,3
820 GOTO 850
830 *FX 7,4
840 *FX 8,4
850 *FX 156,3,252
860 *FX 156,2,252
870 *FX 203,9
880 *FX 3,1
890 TIME=0
900 REPEAT UNTIL TIME=75
910 IF A=5 THEN 920 ELSE 970
920 PRINT**";ACK"; "QSL de "CAL$;": ""
930 REPEAT UNTIL ADVAL(-3)>190
940 TIME=0
950 REPEAT UNTIL TIME=25
960 GOTO 2490
970 PRINT**";ADD$: "de "CAL$;
980 FOR I=ITOH:PRINT**:A$(I):NEXT
990 PRINT** 73s "de "CAL$; :""
1000 REPEAT UNTIL ADVAL(-3)>190
1010 TIME=0
1020 REPEAT UNTIL TIME=25
1030 #FX 3,0
1040 #FX 263,255
1050 TIME=0
1060 REPEAT UNTIL TIME=50
1070 IF MCWS=P$ THEN 1210
1080 PROCdash:PROCspace:PROCdot:PROCdot:PROCpause
1090 PROCdot:PROCpause
1100 PROCpause
1110 PROCdash:PROCspace:PROCdash:PROCdash:PROCspace:PROCdot:PROCspace:PROCpa}
1120 PROCdot:PROCspace:PROCdot:PROCspace:PROCspace:PROCdash:PROCdash:PROCpa}
1130 PROCdot:PROCspace:PROCdash:PROCdash:PROCspace:PROCdot:PROCspace:PROCpa}
1140 PROCdash:PROCspace:PROCdot:PROCspace:PROCdash:PROCspace:PROCdot:PROCpa}
1150 PROCdot:PROCspace:PROCdot:PROCspace:PROCdash:PROCspace:PROCdot:PROCpa}
1160 PROCspace:PROCdash:PROCspace:PROCdash:PROCspace:PROCdash:PROCpa}
1170 REM "Message TRANSMISSION COMPLETE"
1180 PRINT
1190 REM Printer Timing Loop if Required (START)
1200 REM Printer Timing Loop if Required (FINISH)
1210 #FX 205,0
1220 #FX 2,0
1230 #FX 21,1
1240 #FX 15,0
1250 GOTO 2510
1260 GOTO 490
1270 VDU19,0,4,0,0,0
1280 ON ERROR GOTO 1300
1290 PRINT"You are now in RX MODE."
1300 INPUT"Do you require a PRINTOUT (Y/N) ",PRI$
1310 IF PRI$=T$ THEN 1330
1320 IF PRI$=N$ THEN 1340 ELSE 1300
1330 PRINT"TURN PRINTER ON":GOTO 1350
1340 P=0
1350 INPUT"Do you wish to RECEIVE SPECIFIC MESSAGES ADDRESSED TO YOU ONLY (Y/N) ",SM$
1360 VDU19,0,4,0,0,0:VDU3:IF SM$=T$ THEN 1390
1370 IF SM$=N$ THEN 1380 ELSE 1350
1380 PRINT"RX in GEN.MODE. Press 'T' for TX or EXIT MODE.";GOTO 1400
1390 T=5:PRINT"RX in SPEC...(PACKET)...MODE. Press 'T' for TX or EXIT MODE."
1400 GOTO 1410
1410 #FX 14,7
1420 #FX 205,64
1430 #FX 7,3
1440 #FX 8,3
1450 #FX 156,3,252
1460 #FX 156,2,252
1470 #FX 137,1
1480 IF C=5 THEN 1490 ELSE 1580
1490 ON ERROR GOTO 2410
1500 IF SPD$=HS THEN 1510 ELSE 1530
TIME+=E/2,1875)
1520 GOTO 1540
1530 checktime=TIME+E
1540 7&80=0
1550 ON ERROR GOTO 2410
1560 REPEAT UNTIL ?&80<>0 OR TIME)checktime
1570 IF ?&80=0 THEN 2390 ELSE 1500
1580 ON ERROR GOTO 2100
1590 ?&80=0
1600 IF U=5 THEN 1610 ELSE 1670
1610 IF SPD=H$ THEN 1640
1620 setime = TIME+(2*E)
1630 GOTO 1650
1640 ON ERROR 6010 GOTO 21'0
1650 ?&80=0
1660 IF Q:5 THEN 1610 ELSE 1670
1670 IF SPD=H$ THEN 1640
1680 setime = TIME+(E*0.91428571)
1690 REPEAT UNTIL ?&80<>0 OR TIME)setime
1700 IF ?&80=0 THEN 2200 ELSE 1260
1700 REPEAT R=INKEY(0)
1710 IF R=84 GOTO 2120
1720 Until ?&80<>0
1730 *FX 2,1
1740 IF SPD=H$ THEN 1720 ELSE 1730
1750 *FX 156,1,252
1760 7&80=0
1770 REPEAT Xi=INKEY(0)
1780 UNTIL Xi<>-1 OR ?&80<>0
1790 IF Xi<>ASC**** OR ?&80<>0 THEN 2100
1800 IF Q=5 THEN 2530 ELSE 1700
1810 IF T<5 THEN 1850
1820 IF GET=71 THEN 1800 ELSE 2100
1830 IF GET=51 THEN 1810 ELSE 2100
1840 IF GET=87 THEN 1860 ELSE 2100
1850 IF GET=82 THEN 1830 ELSE 2100
1860 IF GET=73 THEN 1840 ELSE 2100
1870 A=5
1880 PRINT
1890 IF P=5 THEN 1870 ELSE 1880
1890 VDU2
1900 PRINT "Message reads as follows:"
1910 finishtime=TIME+3500
1920 REPEAT
1930 Xi=SET
1940 IF Xi<9 THEN 2360
1950 IF Xi>13 THEN 1940 ELSE 1950
1960 IF Xi<32 THEN 2380
1970 IF Xi>12 THEN 2390
1980 VDU1X
1990 UNTIL Xi=124 OR TIME)finishtime
2000 PRINT
2010 IF A=5 THEN 2000 ELSE 2010
2020 PRINT "Message ends.";GOTO 2430
2010 PRINT "Message ENDS.";VDU3
2020 IF T=5 THEN 2030 ELSE 2050
2030 PRINT "RX in SPEC...(PACKET)...MODE. Press 'T' for TX or EXIT MODE."
2040 GOTO 2060
2050 PRINT "RX in GEN.MODE. Press 'T' for TX or EXIT MODE."
2060 =FI 2,0
2070 IF MCW$=P$ THEN 2100
2080 TIME=0
2090 REPEAT UNTIL TIME>750
2100 PROCrxexit
2110 GOTO 1400
2120 PROCrxexit
2130 C=0
2140 T=0
2150 GOTO 520
2160 DEFPROCdash
2170 *FX 203,9
2180 TIME=0
2190 REPEAT UNTIL TIME>20
2200 ENDP
2210 DEFPROCDot
2220 *FX 203,9
2230 TIME=0
2240 REPEAT UNTIL TIME>6
2250 ENDP
2260 DEFPROCSpace
2270 *FX 203,255
2280 TIME=0
2290 REPEAT UNTIL TIME>3
2300 ENDP
2310 DEFPRPCause
2320 *FX 203,255
2330 TIME=0
2340 REPEAT UNTIL TIME>20
2350 ENDP
2360 PROCrxexit
2370 C=0:T=0:P=0:A=0:Q=0:GOTO 430
2380 PRINT "********* MESSAGE CORRUPTED *********:GOTO 2100
2390 PROCrxexit
2400 C=0:GOTO 760
2410 PROCrxexit
2420 P=0;A=0;C=0;Q=0;T=0:GOTO 430
2430 PRINT "Send ACK ROUTINE in progress":VDU3
2440 *FX 2,0
2445 IF MCW$=P$ THEN 2470
2450 TIME=0
2460 REPEAT UNTIL TIME>750
2470 PROCrxexit
2480 GOTO 740
2490 PROCrxexit
2500 A=0:GOTO 2010
Q=5:PRINT"Receive ACK ROUTINE in progress"
C=0:GOTO 750
IF GET=65 THEN 2540 ELSE 2620
IF GET=67 THEN 2550 ELSE 2620
IF GET=75 THEN 2560 ELSE 2620
REPEAT
II=GET
VDU 11
UNTIL II=124:PRINT:VDU3
PROCxexit
Q=0:T=0:P=0:C=0:A=0:GOTO 490
PROCxexit:GOTO 740
DEFPROCxexit
FX 2,0
FX 137,0
FX 13,7
FX 156,2,252
FX 205,0
FX 15,0
ENDPROC
DEFPROCxexit
FX 3,0
FX 283,255
FX 205,0
FX 2,0
FX 21,1
FX 15,0
ENDPROC
APPENDIX 2

Printout of HF Test Message
(Including analysis annotation by recipient)

Message Sent - 46 star characters - line feed char - 51 star characters.

From G3WRI, Kendal, Cumbria on 17th Feb 1985 on 3.655 MHz.

Message Received by G3CZX, Gloucester

Message Reads As Follows:-

```
*******************************
*******************************
Message ENDS.
```

Message Reads As Follows:-

```
*******************************
*******************************
*******************************
*******************************
Message ENDS.
```

<table>
<thead>
<tr>
<th></th>
<th>0101010 *</th>
<th>Data characters without Start/Stop/Parity bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0100010</td>
<td>Except for &quot;z&quot; only 1 bit error from correct word.</td>
</tr>
<tr>
<td>z</td>
<td>0101111</td>
<td>From this I think that hits are due to impulse noise, rather than fade conditions.</td>
</tr>
<tr>
<td>j</td>
<td>0101011</td>
<td></td>
</tr>
<tr>
<td>:</td>
<td>0101110</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>0001010</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td>0111010</td>
<td></td>
</tr>
</tbody>
</table>
Plain Language Packet received without error in Trowbridge, Wiltshire on 3.655 MHz by G3UNU. Dated 5th May 1985.

N.B. Printout rotated through 90 degrees to fit on A4.
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