BRITISH BROADCASTING CORPORATION

AUTOMATED CONTROL SYSTEMS FOR HF TRANSMITTERS

by D.C. Savage, Head of Monitoring and Control Section;
Engineering Designs Department; D.A. Carter, Senior Engineer,
Monitoring and Control Section, Engineering Designs Department;
and G. Hills, Senior Project Engineer, Receivers and Control,
Transmitter Capital Projects Department.

INTRODUCTION

Overseas broadcasting is normally carried out from stations equipped with a
number of high power HF transmitters and a much larger number of aerials, the
latter being a function of the number and location of countries to be served.
Propagation conditions vary according to the time of day throughout the year
and with the sunspot cycle; consequently operating frequencies must be
changed to suit prevailing conditions. Since, in order to achieve the
best utilisation of plant, a single transmitter may during the course of a
day be required to serve several countries, it will be subjected to several
changes of frequency, aerial, aerial bearing and programme feed. Optimum
utilisation of the lines carrying programmes between the studios and trans-
mitters is accomplished by switching different programmes to the lines during
the course of the day. This introduces a further complication, that is the
need to "unscramble" the programmes to ensure that the transmitters are fed
with the correct programme at the correct time.

It is obvious that an HF station of this type will have a complex schedule
of operations to execute. Manual operation of such stations sited within
the United Kingdom has become somewhat labour intensive, when judged by the
standards now being achieved in the domestic broadcasting services, and there
appears to be a reluctance among younger staff to embark upon relevant
operational careers. Consequently there is pressure to automate these stations
as far as possible.

FEATURES DESIRABLE IN AUTOMATIC CONTROL SYSTEMS

The development of remotely controllable HF transmitters and the availability
of powerful microprocessors has made it possible for designers to give serious
consideration to the use of computer technology for the control of all the
operational activities of a shortwave broadcasting station.

It would appear that desirable features of such a system are:
i) It should be capable of storing and executing a large number of events such as transmitter starting, stopping, frequency changes, aerial and aerial bearing changes and programme changes.

ii) Entry of the schedule of events, which typically may be changed twice a year should be operationally easy.

iii) There should be provision to enable both long and short term amendments to be made to the schedule to meet broadcasting needs, and to transfer a service under fault conditions.

iv) The system should incorporate validation features which will draw attention to incorrect entries or typographical errors.

v) Entries should be made in a "language" clearly understandable to an operator, i.e. the operator-to-system communication should be in plain language.

vi) The overall configuration should be such as to afford maximum security and reliability without resorting to equipment duplication.

vii) Maximum use should be made of the feature of microprocessor-based systems which permits the incorporation of inbuilt fault diagnostic routines.

viii) Equipment status should be monitored to ensure that commands have been effected and that events occur in the correct sequence.

ix) Equipment faults should be monitored and alarms given for abnormal conditions, and finally

x) The system should be capable of being accessed from a distant point.

PRACTICAL CONSTRAINTS UPON AUTOMATION IN THE BBC

Programme and aerial switching on UK HF stations is already carried out by electro-mechanical switches so that remote control of these functions poses few problems. The transmitters, however, can be more difficult. The necessity for frequent (and often large) changes in carrier-frequency has, until very recently, rendered manual intervention mandatory. However, in the latest designs of HF transmitters, these changes (which are not a feature of domestic broadcasting) can be achieved by remote control, although even now some designs restrict variation to a fixed number of pre-set frequencies. BBC plant ranges from the latest, continuously-variable (frequency follow) transmitters, to some which are nearly forty years old, with the result that the degree of automation which is practicable to achieve varies from station to station.

The first UK station to be automated (see below) includes six manually tunable transmitters within its complement. It is not practicable to modify or replace these transmitters at this time, and it therefore follows that it is not possible to withdraw operational staff completely, hence that there is little point in providing remote access to the system (feature (x) above) at present. The third station, however, is being re-equipped with new transmitter and as a consequence, the possibility of remote access and intervention, e.g. from the studio-centre, has to be allowed for in the system design.
The nature of the HF stations, and in particular that of their massive aerial arrays, is such that "unattended operation" as understood in the domestic broadcasting area, is probably unattainable in the foreseeable future, whereas the reduction and eventual elimination of normal operational tasks is almost certainly achievable with existing technology.

SYSTEM PHILOSOPHY

The BBC has taken a decision in principle to automate, as far as possible, the operation of all four of its HF stations within the UK. As a consequence the Transmitter Capital Projects Department issued a detailed specification for a control system for the first station. The task of developing this was eventually given to the Engineering Designs Department who, in competition with outside manufacturers, had submitted a proposal which fulfilled the terms of the specification. The two Departments then established a team to undertake the design, development and implementation of the system.

It was agreed that the system should be microprocessor based, and that it should employ distributed intelligence techniques; a modular concept involving a number of identical and relatively simple microprocessor sub-systems. This distributed approach, which ensures that even multiple faults are unlikely to result in a complete system failure, was felt to be preferable on grounds of reliability to that of the single central microprocessor or microcomputer.

The allocation of groups of functions to different units was thought to be another feature which would contribute to overall reliability by enabling certain units to automatically take over the important functions of faulty counterparts, even though in taking over these functions the unit might have to temporarily shed less important ones not necessary to the maintenance of the service. Operator communication it was agreed should be by way of a standard keyboard and visual display system.

IMPLEMENTATION

It was decided that the first UK HF station to be fitted with an automated control system should be the ten-transmitter site at Wootton. This site, which is fed by six programme lines, has six older transmitters which require manual control of carrier-frequency and tuning, and four new transmitters with remotely controllable pre-set frequencies and tuning. The output of each transmitter can be switched to any one of eight manually pre-selected aerial arrays. The total number of arrays is forty, of which four can be remotely slewed.

Schedule Entry

The operational schedules are prepared by Engineers at the Studio Centre, and when a new one is received at the HF station, the information which it contains has to be entered into the control system. To assist in this process the system is arranged to display on request an appropriate form on an intelligent VDU. This form contains schedule information for one transmitter. The columns show the time, daycode, action, frequency, channel, array bearing and chain. By using cursor controls the appropriate parts of this form can be completed; the microcomputer associated with the VDU makes sure that the headings and lines cannot be overwritten.

The microcomputer also checks that the information that has been entered makes sense. It does this in several ways, for example:
1. If the frequency is entered as "1500Z kHz" the Z will be detected as an illegal character and the frequency will not be accepted by the computer until the operator corrects it.

2. The intelligent VDU stores a separate page which shows the bearings that can be selected for each aerial array and this is used by the computer to check that the operator has entered a valid bearing against each aerial array specified on the schedule page.

3. After the schedules for every transmitter have been entered, the computer crosschecks them to make sure that two or more transmitters are never scheduled to drive the same aerial array simultaneously.

Having entered a schedule into the intelligent VDU memory, the next step is to load it into another part of the system that is capable of interfacing with the transmitting station in real time. This raises another problem which is how to load a new schedule and ensure a well-ordered transfer from the old schedule. Broadly speaking, this involves storing both schedules and providing a link, in software, from the old to the new schedule at the appropriate time — analogous to overplugging on a jackfield.

Compliance with Schedule

Having loaded the schedule the system is now in a position to command operation of station plant. It is however important for the system to know whether its commands have in fact been carried out. This is done by arranging for the controlled equipment to send revertive signals that indicate whether each command has been executed correctly. So for instance where four wires are used to send a binary number to select a particular aerial array, four more wires are used to indicate which aerial array has actually been selected. Other inputs to the control system include carrier failure and programme failure. Several of the revertive indications are not valid immediately after a command is sent, so the system is programmed to wait for a predetermined time, and then to compare the state of the controlled equipment with the schedule and if necessary generate an audible alarm and display an alarm message to show the nature of the fault.

System Hardware

An overall block diagram of the system installed at Woolferton is shown in Figure 1.

The microcomputers associated with each transmitter are termed "sender controllers". Each one contains the entire schedule for its transmitter in RAM and it is able to operate independently of the rest of the system. So any single fault on the control system will only normally affect one transmitter at most. "Interface" equipment provides manual control facilities in the event of such a fault.

The sender controllers are joined by a communication network to two more microcomputers called "supervisors". Each supervisor holds the transmission schedule for the entire transmitting station, so the schedule for each transmitter is held in three places: the controlling supervisor, the back-up supervisor and the sender controller. These schedules are continuously compared with one another over the communications "hub" so that any memory corruption can be detected and the appropriate action can be taken. The action taken would depend on the location of the corrupted memory and whether
there is one isolated error or a number of errors. For instance, an isolated error in a sender controller would result in its memory being re-written with data from the two supervisors, which agree and therefore would probably not be corrupted. On the other hand a repeated error would result in an audible alarm being given, and alarm information being displayed. The operator could then reload the schedule.

Both of the supervisors are fitted with VDUs. One of them is used to display the current status of the station, together with a preview of the next scheduled event for each transmitter, see Figure 2. The other VDU is used to display details of alarms, but is interchangeable with the first in the event of equipment failure. Alarm details are also printed for logging purposes.

As mentioned previously the "intelligent VDU" is used for entering schedules, for storing them on floppy discs, and for downloading them into supervisors and sender controllers. The intelligent VDU can also be used for manual control and interrogation of the system. Two equipments are supplied, the second can be used either on-line, as a hot-spare for the first, or off-line for schedule preparation.

Communication between the sender controllers, supervisors and VDUs is provided by serial, bi-directional data links that are effectively connected in parallel in the hub. With such a system it is necessary to ensure that only one device sends a message at any one time and this is achieved by using a polling system which is under the control of the controlling supervisor. In the event of this supervisor developing a fault the second supervisor will automatically take control.

System Maintenance

These are fairly complex systems, for instance the control system which is about to be installed at the second HF station will contain 24 microprocessors, 240 printed circuit boards and about 6000 integrated circuits. With systems of this size it is most important to consider how they should be maintained. The approach has been to build diagnostic aids into the software, so that faulty printed circuit boards can be identified without using expensive and complicated external test equipment. The diagnostic software carries out a number of tasks such as checking RAM, PROM and ports. If a fault is found, an alarm is raised and a four-digit display on the front of a central processor unit shows a code that refers to the particular test that has failed. Code switches on the front panel enable further information to be obtained by making the display show the contents of any memory location. The code on the front panel display should enable a faulty unit to be identified and replaced fairly quickly. To ease the problem of identifying a fault within an individual unit a number of test programs are being written to run on external test equipment.

Software

The software for this system took about four man-years to write and the full assembly code listing, with comments, fills about 400 sheets of A4 paper. The detailed logic is deceptively complex and contrary to popular belief, it is not an easy matter to modify software in this sort of system, without a thorough understanding of its operation. For instance a change in, say, the sender controller will almost certainly have knock-ons in the VDUs and supervisors. The fact that this is a distributed processor, real time control system makes it particularly vulnerable to ill-considered changes. Except
where customer options are concerned, it is always most inadvisable to change software without a very full understanding of the way the computer system operates.

Operational Experience

The first system went into service in mid-1980 and since then the station has been completely under automatic control except for those functions on the older transmitters which still require manual intervention. The system has proved to be reliable, despite the hostile electromagnetic environment which exists at high-power HF stations, and it appears to have been accepted as "friendly" by the staff.

THE FUTURE

As noted previously the BBC intends to automate all four UK HF stations. The second station will also contain a mix of old and new transmitters and a system very similar to that described above, is scheduled to be installed there during 1982.

The third station is to be re-equipped with transmitters of the latest design, and for this the control system is likely to be augmented by the addition of monitoring facilities and the option of remote indication and intervention such that the operational element of station staff duties could be eliminated in the longer term.

CONCLUSIONS

The current state of high-power HF transmitter and microprocessor technology is such that shortwave stations can now be designed to execute complex broadcasting schedules without the involvement of operational staff on site.
Figure 1  Block diagram of control system installed at Woofferton

Figure 2  Typical VDU display