THE BBC NETWORK RADIO TIME AND FREQUENCY STANDARD AND ITS ROLE IN THE PROVISION OF THE GREENWICH TIME SIGNAL

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Abstract

The BBC has broadcast the Greenwich Time Signal (GTS) on its networks since 1924. Up to February 1990 this signal was generated by the Royal Greenwich Observatory (RGO) in England and the BBC was informed that the RGO was moving its location to Cambridge and might not be able to continue to provide the Greenwich Time Service. The BBC in its role of a public service broadcaster believed that a long tradition of providing a time signal to its listeners should be upheld, and as such decided to seek alternative methods of provision.

In parallel with this activity an in–house requirement arose to re–engineer time switch equipment and provide new facilities for digital audio projects. As both requirements have a common engineering core, a decision was taken to design and procure a Time and Frequency Standard that could generate the Greenwich Time Signal to the same specification adhered to by the RGO, and provide additional time and frequency facilities. This paper discusses initially the concept of time and time/frequency dissemination as used in a broadcast network, and follows on to present the details of an engineering solution to the requirements of BBC Network Radio.

Trends in international broadcasting and the commercial telecommunications market place point towards the increased use of digital audio for studio networking and terrestrial links. The synchronisation requirements in this field are more stringent than that incurred in analogue distribution. This paper will consider what timing systems are needed in these applications and how these requirements are satisfied in the BBC Time and Frequency Standard.

Finally this paper will present a fringe benefit of the BBC Network Radio system. This is the ability to obtain UTC time from the system using a modem dial up method from any location in the world. This facility is currently under evaluation within the BBC; and if considered viable will be available to other organisations and companies in the near future.

Historical Background Of The Greenwich Time Signal (GTS)

The measurement and observance of time in advanced industrial societies in the present age merits a high priority. Yet this was not always so. Scientific interest in the measurement of time using astronomical and other methods has an old and well established history, but the transfer of a standard time and time keeping to the general public was largely dominated by the railway companies.Quaint as it might have been in England to board a train at London time, and leave the same train on the same day at Plymouth time, these local variations were generally considered unhelpful to the operational management of England's railways.

Following the International Meridian Conference of 1884, a time zone system based on the Prime meridian at Greenwichwas adopted by many countries. Dissemination of time, particularly to the general public, was largely dominated by the "six pips" Greenwich Time Signal (GTS) which was conceived by Sir Frank Dyson, the ninth Astronomer Royal of the Royal Greenwich Observatory (RGO).

Following discussions with John Reith of the BBC, GTS was launched at 9:30 PM on the 5 February 1924 when six short pips were broadcast. The timescale reflected Greenwich Mean Time as determined from astronomical measurements. Initially the "pips" were derived from a Shortt pendulum clock, but in later years atomic clocks were employed. The timescale now adopted is UTC and GTS as heard today consists of five short pips of 100 ms duration and a final pip of 500 ms duration, the start of which marks the exact minute. The longer pip was introduced to make identification of the final pip a more exact process. See Reference 1 for further information.

Time And Frequency Dissemination Within The BBC Radio Network

From The Past To The Present Day

While the listeners were on the right time, courtesy of the RGO, it was equally important to ensure that all departments of BBC Radio were also on the same time. Different techniques for obtaining and disseminating time have evolved over the years. In the pre–microprocessor age cost has been a dominant factor, and a popular system has been the pendulum master impulse clock driving multiple slave units. This type of system has been used for many years at Broadcasting House although its days are numbered. A familiar problem with any oscillator is that of drift, and an ingenious mechanism is employed in this clock to correct the drift using GTS at 3:00 AM each morning. The synchronisation element was the addition or withdrawal of a carefully calculated weight from the pendulum, the effect of which caused the clock to run slow or fast as required.

In 1977 it was decided to upgrade time facilities at Broadcasting House by the installation of an off–air reference tuned to MSF60. This system fed selected technical areas of BBC Radio with a real time code that was used to drive display clocks and operate time switches.

Frequency dissemination in BBC Radio consisted of free running ovenised crystal oscillators which were installed as a component of specific equipments. Small groups of equipment were locked together as required, but no master frequency distribution existed as such.

From The Present To The Future

Two years ago a decision was taken to re–engineer all timing systems as current equipment was obsolete and inadequate for perceived future requirements. Concurrent with this period the RGO announced they would be moving site from Sussex to Cambridgeshire and the continued provision of GTS was in doubt. As such it was decided to incorporate the means to generate GTS within the new system, and maintain it to the same degree of accuracy as that offered by the RGO.

Technology now available for the generation of studio quality digital audio has pointed the way forward to the all digital broadcast centre concept. The design of such a system required an AES/EBU code master clock with an accuracy greater than 1×10^{-7}. At this time no master distribution existed for this purpose. (AES/EBU abbreviations refer to Audio Engineering Society/European Broadcasting Union.)

The requirements of the new system were as follows:

General

To use equipment off–the–shelf wherever possible and to employ international standards for the dissemination of information, thus permitting easy expansion of the system without the additional work of building special interfaces.

Time

- Obtainment of an off–air time reference from at least two sources for UTC and TOD (Local Time Of Day).
- Generation of a broadcast standard timecode, locked to the off–air time reference, to disseminate time and date information within Broadcasting House.
- Generation of GTS to the same degree of accuracy as that of the RGO.
- Provision of a speaking clock.
- Provision of an AES/EBU digital audio master reference clock, with the inherent timecode locked to the off–air reference.
- Dissemination of UTC and TOD to other BBC sites, and other organisations as required.

Frequency

- Provision of an atomic oscillator system to sustain the Time Standard in the event of loss of off–air reception.
- Provision of frequency clocks, locked to the Frequency Standard, to satisfy user requirements as required.

System Management

- To use off–the–shelf computer hardware, thus providing a capital cost benefit and ease of maintenance by the use of standard boards.
- To use an industry standard operating system (OS) thus permitting flexible expansion of facilities.

System Solution

The system layout is illustrated in Figures 1 through 4. Each part is now described:

Time And Frequency Standard

TIME:

Time is received off-air from GPS and MSF. GPS is used as a UTC reference and to provide an accurate 1 PPS time mark for comparison with other equipment, while MSF is primarily used as a reference for British Time-Of-Day (TOD). A time voting switch (TVS) compares the time of all three receivers via their IRIG B outputs and provides two feeds of UTC and TOD in IRIG B format to the system management computer. If the voting process itself fails the TVS may be used as a stand alone generator to create UTC and TOD outputs as required until normal operation results. Refer to figure 1 for system diagram.

FREQUENCY:

Two GPS disciplined rubidium oscillators, each internally fitted within each GPS receiver, are used to form a dual redundant 10 MHz frequency standard. The long term stability of GPS is excellent and the drift/year of this system is typically 3×10^{-12}. As such this system provides a high degree of accuracy without the punitive maintenance costs of a Cesium system. Refer to Reference 3 for further details.

Dissemination Of Time

GENERAL:

Time dissemination facilities are built around the Leitch CSD5300 clock system controller which provides time output in a variety of formats. Refer to figure 2 for system diagram. These equipments may be controlled *via* a 300 baud RS232 interface or may be set manually via a front panel keyboard. A 10 MHz external frequency reference from the Frequency Standard is used to drive all time dissemination equipment thus ensuring tight control of each 1 PPS internal reference. The 1 PPS time mark in each clock unit is compared with the 1 PPS time mark reference from GPS and is set coincident, advanced or retarded according to user requirements.

Greenwich Time Signal

The Greenwich Time Signal is itself generated from a Leitch CSD5300 and its 1 PPS reference is advanced to compensate for the delay in the transmission path from Broadcasting House to the transmitter. Off-air measurements are made on GTS and the derived 1 PPS is again compared with the GPS RX 1PPS reference. BBC Network Radio aims to maintain GTS within ±2 ms of UTC on Radio 4 as transmitted on 198 kHz. GTS is also sent via private wire circuit to BBC World Service. At the moment GTS transmissions on the short wave network are not fully compensated for transmission channel delay.

TIMECODE DISTRIBUTION:

A realtime signal in the form of EBU Timecode is generated and distributed, to both technical and public areas of the building. This signal is used to drive self setting analogue and digital clocks, a digital voice announcer (speaking clock) and is also used as a timecode reference for audio tape recorders and time switches. As this signal spectrum falls within the audio band it is easily networked within a broadcast centre.

Refer to reference 4 for further details on this system.

REMOTE TIME:

A fringe benefit of the time dissemination facilities is the ability to obtain time via a modem link. This facility, which incorporates automatic path delay compensation, is used by various regional BBC premises to obtain a reference for their local clock control equipment, and has proved to be accurate for these purposes. Time transfer accuracy of ±1 ms ±modem error is quoted by Leitch. The BBC system employs CCITT tones and Hayes 1200 smart modems Experiments are in progress to judge the accuracy of this system. Dial-up time facilities are available for UTC and TOD.

Dissemination Of Frequency

FREQUENCY CLOCKS:

Frequency generators using Oscilloquartz VCXO's are employed to provide specific frequency clocks to user requirements. These generators are locked to the 10 MHz frequency standard, but in the event of a failure of this reference the modules may freewheel. On restoration of reference a long time constant is used to permit smooth operation of the PLL. The use of separate modules in this manner makes it simple to expand the system or locate modules of this type at another location.

AES/EBU MASTER CLOCK:

This module provides a digitally encoded stereo audio signal, with a bit rate of 3.072 Mb/s, locked to the 10 MHz frequency standard.

EBU Timecode carrying TOD information is also inserted into the bitstream. This signal is used as a master clock reference for digital audio studio areas and for multiplexed digital audio routing systems.

Refer to figure 3 for a system diagram.

System Computer

A modular based computer system is employed to read IRIG B format time signals and 1 PPS time mark reference from the TVS. Time Dissemination modules are then set to UTC, TOD or user specified time as required, and automatic monitoring is used to ensure that neither the set time nor the 1 PPS drifts out of time setting. As the system resides in an unmanned apparatus room an Ethernet interface is used to convey control to the Network Radio Engineering Operations Centre, where control may be picked up by a number of operating positions.

Refer to figure 4 for system details.

Acknowledgements

The author would like to express his thanks to the Director of Engineering of the BBC for permission to publish this paper. In addition the author would like to express his thanks to Tony Seabrook, formerly of the Royal Greenwich Observatory at Herstmonceux, England, for his advice at the design stage of this project.

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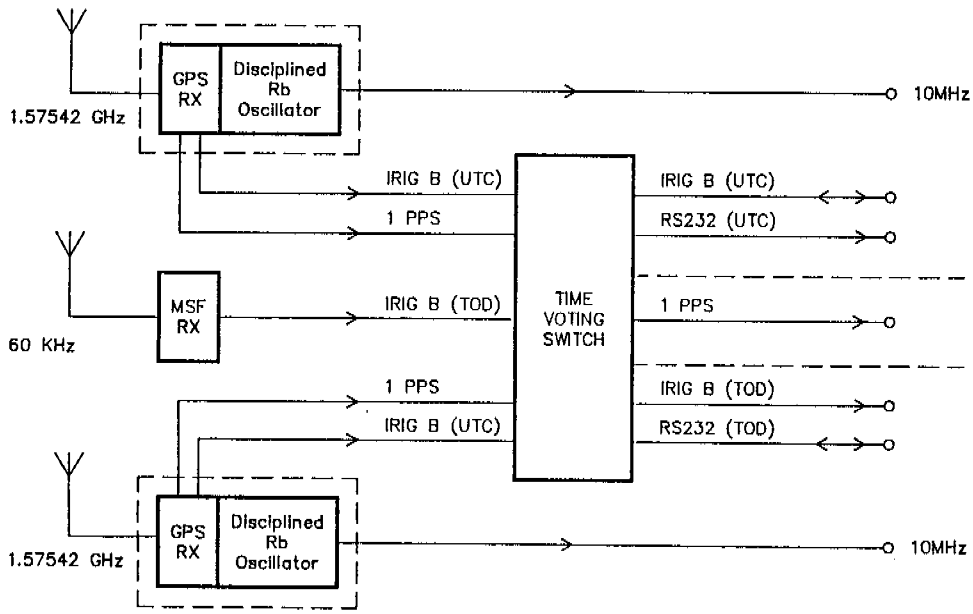

Figure 1: Time and Frequency Standard

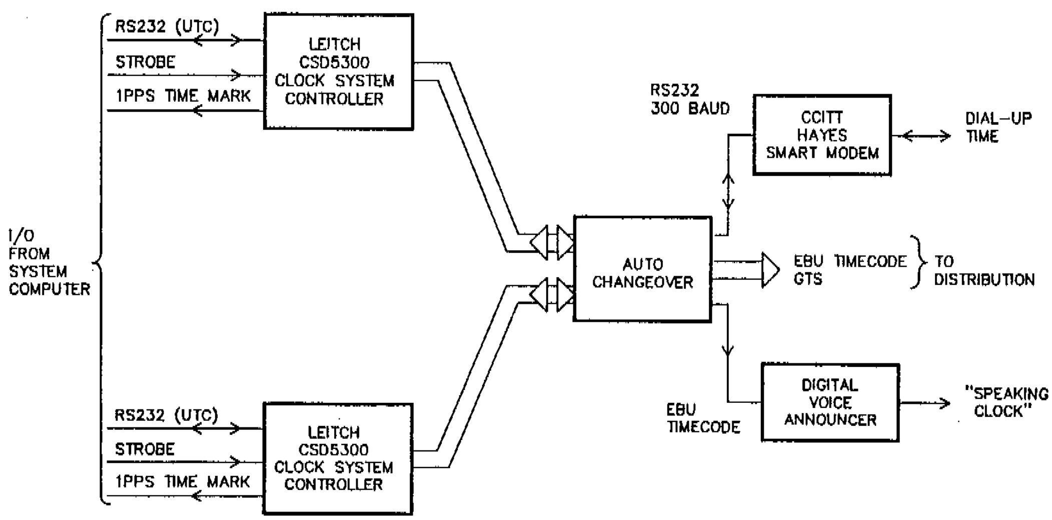

Figure 2: Time Dissemination

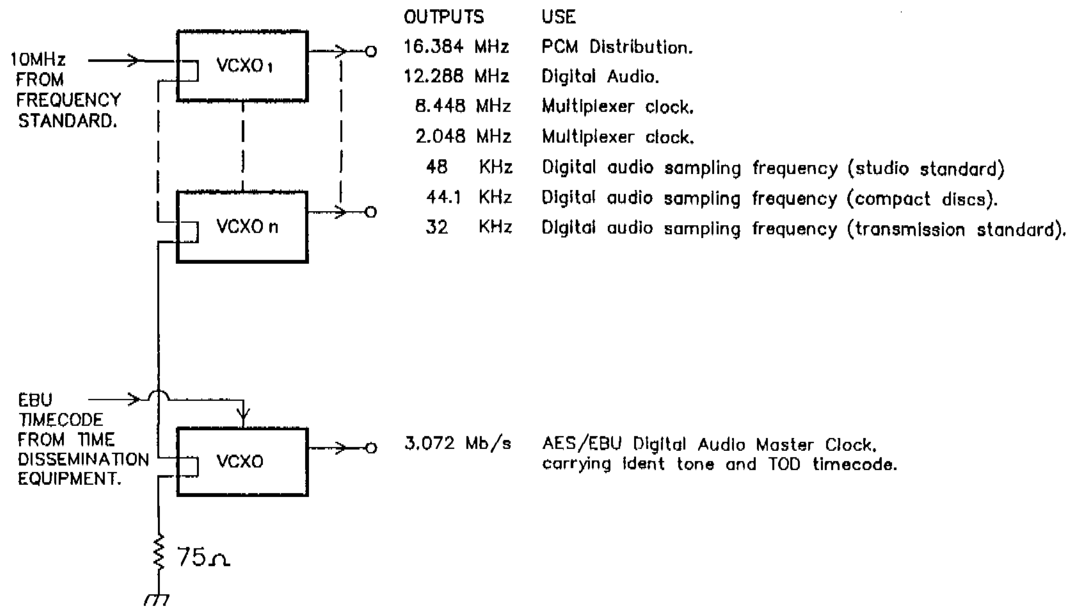

Figure 3 : Frequency Dissemination.

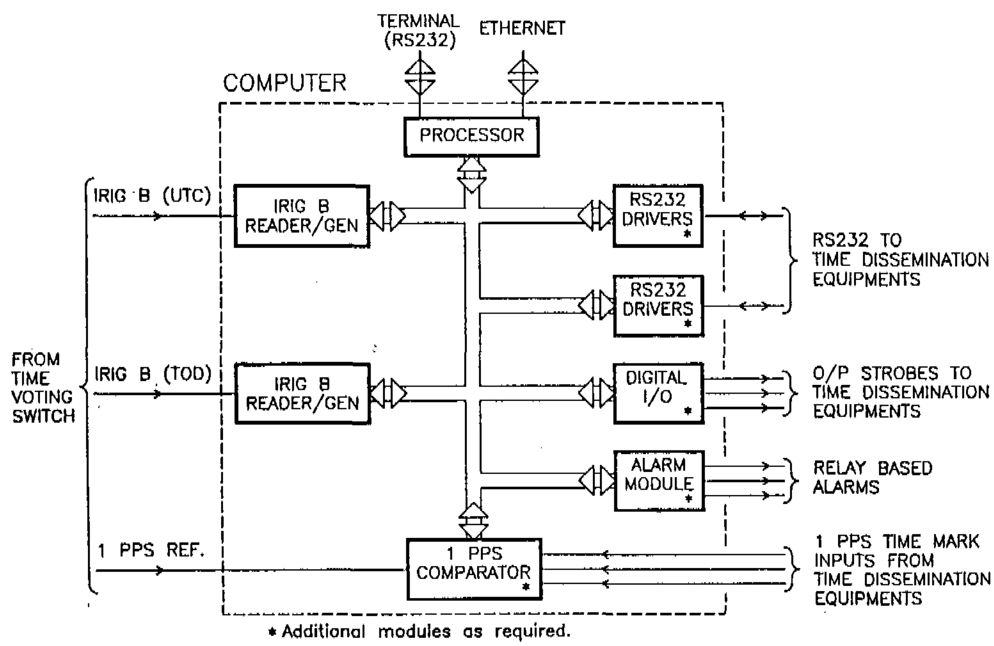

Figure 4: System Computer