A BRIEF SURVEY OF SOURCE SYNCHRONISATION

1. Synchronous Sources

In order to allow mixing, superimposition, inlay etc., of contributions to a programme, the contribution signals must be in time coincidence with each other at the mixing point. For monochrome television "time coincidence" means within 0.1μsec. In a studio centre all the local sources - studio, telecine, etc. - get their synchronising and blanking waveform from a central generator and exact time coincidence is easy to achieve by building out the delay between waveform generator and picture sources to be the same in all cases.

2. Non-synchronous Sources

All sources at present have the recurrence frequency of their waveform generators locked to a common reference, the mains supply frequency, but the relative phase of their sync waveforms is random. Contributions which are not in time coincidence at the mixing point are termed "non-synchronous" and can only be switched by cutting or fading to black. If a switch is made from one source to another whose field syncs are more than about seven lines displaced in time, then receiver and picture monitor time bases have to "change step" and a frame slip or rollover occurs.

The TV/FMU/1 Fading and Mixing Unit was of course introduced to permit non-synchronous sources to be switched by the fade-to-black method; the frame slip occurs at black level and is not objectionable on a properly set up receiver.

3. Slavelock

This is a method of synchronising one or more remote sources to a central waveform generator, so as to bring them into exact time co-incidence at the mixing point. It works by comparing the sync waveform from the remote source with that of the central generator, and sending a controlling signal back to the remote source via a communication channel. One version, the Shone System, used for the Coronation in 1953, sent a 10,125 c/s signal over a telephone pair to each O.B. point, the phase of the signal being adjusted by means of a phase-shifting goniometer until time coincidence with the central waveform was obtained. The system was used on a small scale afterwards but appears to have fallen into disuse because the instability of O.B. waveform generators made it necessary to have a slavelock operator at the mixing point with additional high-grade waveform monitors, etc.

Even if the waveform generators were cleared up (and this has not yet been successfully achieved) the system although operationally convenient would necessitate a communication channel to each remote source. Until recently it was thought that this would have to be an exclusive line, at least for long distance work, and it was also thought that the controlling signal divided down to about 3 kc/s might be disturbed by random phase changes on repeatered audio or carrier circuits. Such changes are known to have occurred during trials of transmitter synchronisation with 6000 c/s tone in 1938, but no one appears to have carried out any recent tests.

Research Department have now proposed a scheme whereby the controlling signal is to be sent out in the form of pulses on a line or lines of field blanking on the network distribution signal. This sounds an elegant solution; it would of course have repercussions on the design of Test Line Signal erasers.

4. Genlock

Appeared in 1954. A General Electric (U.S.A.) invention. This system is the reverse of slavelock, in that the waveform generator at the central mixing point is controlled by that at the remote source and is effectively locked to it. Therefore only one remote source may be used with genlock at any one time, and if a number of remote sources are contributing to a programme they must each take over control of the central waveform generator in turn. Additional equipment is required at the central point only.

Genlock has numerous disadvantages. While the central point is genlocked to a remote source, there may be other programme operations going on simultaneously - closed circuit recordings, contributions to regions, Ampex reproductions, etc. When genlock is applied, the phase of the central waveform generator is changed by dropping lines at the rate of 4 per field until it comes into time coincidence with the remote generator. This causes disturbances to receivers (particularly those with flywheel sync circuits) and to other programme operations; in particular film and video tape recorders and reproducers which are driven from or referred to the Central waveform generator cannot follow the electronic changes quickly and complete break-up of pictures for several seconds can occur.

If the genlock control is broken, the central waveform generator reverts to mains lock and may therefore change its phase; the controlling source may well be connected to the central point by an exceedingly tenuous vision link and the whole of the programme operations at the centre could be at the mercy of, for example, a radio camera.

Genlock brings many operational pitfalls. It has been found from experience that double genlock increases the possibility of failure considerably. A typical case of double genlock is Lime Grove being genlocked to an O.B. and at the same time being genlocked by Television Centre (because the latter wants a telecine insert from Lime Grove).

It is necessary to restrict genlock bookings severely in order to avoid interference with telerecording operations. This situation has been alleviated by providing a second waveform distribution chain at Lime Grove, with switching arrangements so that telerecording etc., operations can take place without interference while programmes requiring genlock use a second chain. This is a palliative but not a cure since there will be occasions when a third or fourth chain would be desirable. At a new C.B.S. television centre which is now being planned, there are to be seven waveform distribution chains, each with its associated spare generator, distribution amplifiers, switching, test waveform generators, etc!

Designs Department have now produced an improved form of genlock equipment which is undergoing field trial at Television Centre. It operates more slowly than the Pye system, taking about 25 seconds if the two generators are in antiphase to start with (about 1 line per 6 fields), and achieves phasing by altering the frequency of the master oscillator. This improved system all but eliminates interference with other sources, except that Ampex reproductions may show "Switcher marks" (the horizontal white lines which appear when the heads are not being switched at the right instant). Twenty five seconds is however too slow for some programme requirements - e.g. a recent news round-up when a number of regions were "visited" with 8 seconds between regional inserts.

The Designs Department device can also be used for slavelocking, transmitting a 20,250 c/s control frequency variable in phase over a line to a remote source.

5. Field Phasing

This was the next development. It was introduced in order to permit cutting between non-synchronous sources without roll-over; it requires no facilities other than a 50 c/s variable phase shifting device connected between the mains and mains reference input of each waveform generator, and a control line. The mixing point talks the remote source into field phase, i.e. within a few lines. For avoidance of roll-overs it does not matter if the remote source and central point are one field out, i.e. odd coinciding with even, since the receiver does not notice the deceit. It is quite easy to field phase to 2 lines on a high grade waveform monitor.

All methods of synchronisation suffer from the disadvantage that the remote source must be available at the mixing point before it goes on transmission in order to determine the error. However, if for example the Manchester - London vision circuit is blocked until the moment of transmission, field phasing can still be carried out. The The delay between London and Manchester is 11½ lines. Therefore, if a contribution coming into Manchester Switching Centre is adjusted so that it is 23 lines in advance of network distribution at Manchester, the remote source will be in phase with network programme at Television Centre, provided Television Centre does not change phase meanwhile by genlocking to some other source.

Field phasing suffers from instability of waveform generators and various other factors. For example, a sudden increase in load on the grid has been known to cause a phase change of 20° (about 10 lines). In order to avoid positional distortion on receivers with flywheel time base synchronising circuits, waveform generators have a spongy lock to the mains so that only slow variations can take place, but this means that the phase of the field waveform relative to the mains can swing about over a number of lines. Field phasing to be really successful therefore requires careful monitoring, with staff implications. However, it is a valuable facility and all remote sources are field phased whenever possible during the 15 mins. before transmission.

It was soon realised that field phasing is an essential adjunct to genlock. If the remote source is field phased to within a few lines before genlock is applied, the genlock circuits only have a small amount of correction to carry out and the effects on other sources at the central point are lessened. For this to be effective it is necessary to bring the signals into picture coincidence, i.e. odd field must coincide with odd field and the operation should strictly be called picture phasing.

A device developed by Messrs. Anstey and Pover at Television Centre is about to undergo field trial; this enables field phasing to be mechanised and carried out more accurately. It compares the 10 sec. positive going pulse at the end of the broad pulses in the even field of the remote source with the same pulse of the central generator; and by means of a gating circuit it produces a 10 sec pulse in the picture period of the first line of field blanking of the even field of the network distribution waveform, when the two waveforms are within 1 line of coincidence. Phasing is carried out at the remote source and provided the operator there can see the network distribution waveform he merely turns the handle until the indicator pulse appears.

If network signals are not available (e.g. an O.B. point where radio reception is poor or impossible) indication can be given over the engineering/production control line by a burst of tone. Telephone communication is still required, because the remote source has to be told when everything is ready for him to field-phase, but it is just a matter of giving the go-ahead, field phasing being carried out without close co-operation. The indicator pulse is only present while field phasing is being carried out and has little annoyance value on a picture monitor.

This system does not, of course, overcome the disadvantages of field phasing mentioned above.

6. Standards Conversion

This can be used to make a remote source synchronous. It has been used a few times on domestic contributions but is not popular because of the resultant degradation in picture quality, and it is a cumbersome solution at present, requiring operators for considerable periods.

7. Video Tape Recording

The normal Ampex recorder/reproducer is a non-sync source, the capstan and drum carrying the heads being indirectly mains-driven. In order to make it a synchronous source, Ampex developed -

Inter-sync. In this, the field pulses and line pulses recorded on the tape supply information which controls the instantaneous position and velocity of the drum. It is said to provide an accuracy of 0.1 sec relative to the local sync pulses which provide the reference information, almost good enough for the usual mixing operations. This performance will only be achieved if the local syncs are of highly stable frequency.

It is still not quite good enough, residual errors existing, and Ampex therefore produced -

Amtec (Automatic Time Element Compensator) In this, an error signal developed by comparing the line sync pulse with an external stable reference is converted into a voltage which is applied to silicon junction capacitors controlling a high speed variable delay line in the signal path. This is said to bring the starting time of each line to within 0.03 sec of the external reference waveform. This is still not good enough for the colour sub-carrier. Hence-

Colour-tec which is a further refinement, similar to Amtec, with a shorter delay line and bringing the sub-carrier shift "within the hue shift tolerance of a subjective colour picture".

The required accuracy of the 4.43 Mc/s (625 lines) colour sub-carrier is said to be about .001μsec, i.e. time coincidence has to be about 100 times better than for monochrome.

8. Asynchronous Operation (See note at end)

This means that all waveform operations would be controlled by crystals and there would be no common reference as now (the grid). Crystal oscillators are available which have a stability of about 1 in 10^9 if installed permanently; it is thought that 1 in 10^7 would be possible for MCRs. (the existing crystal control which is fitted to Marconi waveform generators has a stability of about 1 in 10^5).

1 in 10^7 means that the drift would be 0.1 sec in 1 sec, or 100 sec (1 line) in about 16 minutes. This is adequate stability for field phasing - remote sources would of course have to be field phased as now during pre-transmission line-up, and the Anstey-Pover system would help with this. But crystal control is not adequate for accurate time coincidence - with a 1 in 10^9 master oscillator, the tolerance of 0.1 sec would be reached in 100 seconds.

If asynchronous operation were to be brought into use before high stability master oscillators were available for all sources, it would be necessary to provide a common 50 c/s reference in place of the grid supply. Tests have shown that direct transmission of 50 c/s over music lines is likely to be useless due to amplitude distortion effects, the phase shift round a 400 mile loop changing by 90° for a 3dB change in sending level. Further tests sending 50 c/s by double side band modulation of a varrier of a few kc/s over a similar circuit have indicated that such a solution would be satisfactory for field phasing purposes, a change of 10dB in level being required to make a phase change of 3° (about 2 lines).

The solution as propounded by Research Department is fully automatic slavelock synchronising of field pulses, line pulses and, eventually colour sub-carrier. Television Centre syncs would remain rigidly locked to a high stability crystal. Error signals would be sent out on distribution field blanking or, if necessary, in some cases by telephone line, and would automatically correct each source. This still does not solve the problem of synchronising a source which may not be available in London until it goes on the air.

9. Network Delays

Any source can normally only be synchronous at one destination at a time. This is one of the problems to be faced in developing a universal synchronising system, and the solution does not seem at all obvious.

Delays which have been measured on the S.B. network are as follows:

LO - BM - LO	14 lines
LO - MR - LO	23 lines
LO - GW - LO	63 lines
LO - BS - LO	14 lines
LO - CF - LO	20 lines
LO - ROW - LO	10 lines
LO - TOLL - LO	8 lines
BH - TC - LO	75 μsecs.

10. Waveform Generators

The Ferguson transistorised waveform generators now in fairly widespread use do not appear to suffer from the phase instability which is common in Marconi generators.

11. Miscellaneous Information

A few facts which have emerged about the stability of various sources:

The P.O. frequency standard known in the BBC as "Y tone" has a stability of $\pm$ 1 in 10^{8}; it is adjusted about once a month against their primary standard which is about 2.8 in 10^{11}. Drift during a day is less than 1 in 10^{9}.

The latest P.O. coaxial carrier systems have a master oscillator stability of 1 in 10^{7} and are checked weekly against the 1 in 10^{8} Dollis Hill standard. This means that on the top channel of the top supergroup a shift of rather less than 2 c/s can occur if the two ends of the circuit use their own crystal oscillators. It is the normal practice, however, to transmit the master oscillator frequency over the coaxial as 60 kc/s or 308 kc/s. When coaxial systems are used in tandem however a common master oscillator frequency may not be used.

Older carrier systems are not as good and a shift of 2 c/s can occur.

Droitwich on 200 kc/s has a long-term accuracy of +2 in 10^{8} (it always drifts in the positive direction) drift over 24 hours being 1 in 10^{9}.

NOTE Asynchronous operation has advantages in permitting the use of precision offset of transmitter carriers and the use of Intersync, etc. with Ampex VTRs.

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