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SUBJECT: REPORT ON SOURCE SYNCHRONISATION OF CHURCHILL FUNERAL

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24th February 1965

The accompanying report and diagram describe the methods used to achieve synchronous working of the multiple sources contributing to the Sir Winston Churchill Funeral programme. Details are given of the equipment used, the techniques involved and the practical results achieved. On the basis of this experience a number of conclusions are drawn and recommendations made.

The report is issued for information and interest and a limited number of extra copies are available if required.

ABP/BEX

A.B. Palmer

REPORT ON SOURCE SYNCHRONISATION ARRANGEMENTS FOR CHURCHILL FUNERAL PROGRAMME

Introduction:

A determined effort was made to make all the vision sources contributing to the Churchill Funeral programme mutually synchronous at the central mixing point in St. Paul's Cathedral. This was desirable so that cutting from one source to another caused the minimum of disturbance to receivers and recording equipments.

Apart from the 10 cameras used in the Cathedral itself, there were 15 remote O.B. sites (comprising a total of 26 cameras) and a video tape reproduction from Television Centre. A large number of intercuts were made between these 17 separate picture and sync. sources during the four-hour programme.

The attached schematic diagram shows the arrangement of equipment and circuits which was used to achieve source synchronisation. The diagram is somewhat simplified compared with the actual installation, for instance the mixers are in skeleton form and no distribution amplifiers are shown, but it illustrates the principles and methods used.

Throughout the report the remote sites are identified only by their allocated number. For interest, a list is given below of their actual location:

Site 1 - New Palace Yard
Site 1a - Gt. George Street
Site 1b - Richmond Terrace
Site 2 - Trafalgar Square
Site 2a - St. James' Park
Site 3 - St. Mary-le-Strand
Site 3a - Bush House
Site X1 - Cannon Street

Site 5 - Eastcheap
Site 6 - Tower
Site 6a - Tower Bridge
Site X2 - Southwark Bridge
Site 7 - Unilever House
Site 9 - Royal Festival Hall
Site 10 - Waterloo Station

Extent of Synchronous Working

The main sync. pulse generator in St. Paul's was nominated the master S.P.G. and all other S.P.Gs. in the system were made either fully synchronous with, or carefully picture phased to, this pulse train. This master sync. train is, therefore, referred to as the 'reference syncs.' Fourteen of the remote sites were made fully synchronous with the reference by slavelock methods. The fifteenth site, Site 2a, could not be slavelocked due to lack of equipment and lines (this site was introduced only shortly before the funeral) and this was, therefore, taken non-sync. into the mixer.

The video tape input was also taken non-sync. because at present video tape machines are not amenable to slavelock. The possibility of locking the whole St. Paul's system to the video tape input was considered but discarded as unreliable and impracticable. It might have been possible to lock the whole system to the output of a Television Centre pulse chain and then to run up the video tape machine also locked to this pulse chain. However, this would require another vision circuit from Television Centre and would have increased complexity and reduced flexibility, so this method was not adopted, and non-sync. picture-phased cuts to and from video tape were accepted.

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Slavelock Principles

As stated above, 14 remote sites were slavelocked to the St. Paul's reference. As the diagram shows, the slavelock method was more complex for some sites than others. To assist the understanding of these methods a brief explanation of slavelock is given below:

The slavelock system considered here is that based on the BBC Designs Department picture synchroniser UN1/522(P). This unit is known as a slavelock transmitter (in this context) and is situated at the master station. It contains an oscillator which generates an output sine wave of twice line frequency, i.e. approximately 20 Kc/s on 405-lines. This 2LF is fed to the remote slave site where it provides an external master oscillator input for the remote S.P.G. (these circuits are shown in blue on the diagram). The S.P.G. pulse outputs (in green on the diagram) are then fed to cameras, mixer, etc. at the remote site and the resulting composite video signal (red on the diagram) is fed in the normal way to the master station mixer.

At the master station a feed of this slave vision signal is fed into the slavelock transmitter together with a supply of master syncs. The two sync. trains are compared by discriminator circuits which detect any timing difference and cause any error to alter the frequency or phase of the 2LF oscillator in such a way as to reduce the timing difference.

The control is such that the incoming syncs. are brought into step with the reference, first in the picture phase sense, then in the line phase sense, so that ultimately they are brought and held synchronous with the reference within a fraction of a micro-second. Indicator lights fed by the transmitter show the state of lock existing - amber meaning "attempting to picture phase", green meaning "attempting to line phase". (Red means "attempting to mains lock" which occurs in the absence of a reference train.)

The slavelock transmitter is designed so that the changes of frequency of the 2LF oscillator can only occur very slowly (except for small phase changes where the response is rapid) so that subsequent mechanical recording equipment will have little difficulty in following the change of field rate which occurs when pulling into picture phase.

The 2LF signal sent to the remote site travels over a normal balanced sound pair, but it is necessary to ensure that the line attenuation at 20 Kc/s (or 30 Kc/s on 625-lines) is no more than about -25 dB and that there are no sudden changes in phase characteristic around this frequency. At the remote site, the 2LF signal is amplified by a slavelock receiver and this unit also contains a detector which indicates by a green light "suitable 2LF signal incoming" or by a red light "no (or low level) 2LF incoming". In the latter, red, state a local 2LF oscillator is substituted within the receiver so as to provide a signal to drive the S.P.G., which would otherwise stop operating completely. The frequency of this local standby 2LF oscillator is adjusted to be as near as possible to the master 2LF.

Within the transmitter is an important control - the "re-set" button. Pushing this (or losing the slave video) breaks the slavelock loop and sets the 2LF oscillator frequency to approximately the correct frequency, should it be well off for some reason (just switched on, or loop having been broken elsewhere for a while.) Note, however, that this change of frequency is rapid and should not normally be made if the controlled source is being recorded at the time.

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Methods Used at Various Sites

Six of the remote sites were slavelocked in the simple one-loop manner described above (Sites X1, 5, 7, 8, X2).

Site 1 was slavelocked to St. Paul's but then in turn it slavelocked two sub-slaves, Sites 1a and 1b and the outputs of all three were mixed at Site 1. Each loop was, therefore, simple, but the combined trio was rather more complicated. An important factor with this arrangement is that the syncs. fed to St. Paul's from the Site 1 mixer must always be those from Site 1's S.P.G. and not those from Site 1a or 1b. In other words the Site 1 mixer must be used in the 'sync.' mode, the 1a or 1b syncs. being stripped off and replaced by Site 1 syncs. If this is not done, instability will probably result and lock will be lost.

Sites 3 and 3a were also such that both outputs were fed along one vision line to St. Paul's, having been mixed at Site 3. Cascade slavelock could have been used here, as at Site 1, but lack of slavelock units prevented this, so an alternative was adopted. Site 3a, the distant site, was slavelocked to St. Paul's and Site 3 was genlocked (Ferguson fast genlock) to the 3a vision input to its mixer. When 3's mixer was cut to Site 3, the genlock stage was introduced into the 3a slavelock loop, i.e. the 3a S.P.G. was being controlled according to the timing of Site 3's pulses arriving at St. Paul's. This technique worked reasonably satisfactorily although the lock was not quite so reliable as with the simple method. It produced rippled edges on the picture with one S.P.G. at the genlocked site for no obvious reason.

Sites 6 and 6a were locked in exactly the same manner as 3 and 3a. In both the genlocked sites the mixers were operated 'non-sync.' so as to minimise the time during which the genlock stage was inserted in the loop. This has little disadvantage because the non-sync. cuts on these mixers (M.C.Rs. 20 and 28) are good. Non-sync. cuts at Site 1 mixer (M.C.R. 14) are relatively poor.

Sites 2 and 2a were also fed along one vision line into St. Paul's and were mixed at Site 2. However, here Site 2a was not slavelocked at all and was taken non-sync. at Site 2 and St. Paul's. Whilst 2 was fed, the 2 slavelock loop was, of course, broken and its 2Lf drifted wildly. It was necessary, therefore, to allow time to re-establish slavelock on returning to sending Site 2 to St. Paul's. This factor had to be borne in mind by the Producer - Site 2 should not be used immediately after using Site 2a, although the reverse was quite possible.

At all remote sites and at St. Paul's, a reserve S.P.G. was available and all generators in the system (35 in all) were carefully mains lock picture phased together within a line or so. Thus, any site could revert to local mains lock should the need arise and still preserve at least picture phasing.

At Television Centre the video tape reproducer (VT.8) was picture locked to pulse chain 4B which had itself been picture phased so that the video tape signal arriving at St. Paul's was in step with the reference.

The St. Paul's Mixer

Thus, it will be seen that all contributions to St. Paul's were either fully synchronous with St. Paul's or picture phased thereto. The mixer at St. Paul's was a combination of two 10-channel mixers, one carrying the 10 St. Paul's cameras, the other, 10 remote sources. A pre-selector switch extended the latter to 11 sources plus a spare. This second mixer could only be operated either with all channels in the 'sync.' mode or all non-sync.

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(Note. In the 'sync' mode a mixer strips off incoming syncs and replaces them with local syncs. In the 'non-sync' mode it again usually strips off the syncs but replaces them with the same incoming syncs. In the former mode, vision cuts do not affect the output sync train at all. In the latter there is invariably some sync disturbance on a cut - the amount depends on the goodness of the mixer design.)

Since some of the contributions were non-sync (Site 2a and video tape) the mixer, therefore, had to operate in the non-sync mode even when cutting to and from synchronous sources. Fortunately the non-sync cuts on this mixer are good so that this was of little disadvantage. (If the non-sync cuts had disturbed the sync train appreciably this would, of course, have neutralised all the efforts made to make the sources synchronous.) Operation of the mixer in the non-sync mode was also much safer since any loss of lock on a source whilst transmitting had only a mild effect. If working in the 'sync' mode the picture would have been unrelated to the accompanying syncs with catastrophic results.

Slavelock Control Point

In the St. Paul's Control Room the Slavelock Transmitters were arranged in a stack fed with the necessary vision, sync and 2Lf lines and all indicator lights were grouped alongside. Four of the Slavelock transmitters and receivers used on this production were borrowed from Television Centre and Studios.

Access was available to the multiway preview system so that any source could be selected by pushbutton and displayed on a picture monitor and CRO. The monitor was externally locked to Reference syncs so that the state of synchronism of any selected vision was immediately apparent.

A further unit was made use of, namely a Picture Phase Comparator which indicated continuously the number of lines of timing difference between selected video and the reference. This was most useful when setting up picture phasing.

The Master S.P.G. at St. Paul's was mains locked via a manual goniometer so that the whole system could be altered in phase with respect to mains if necessary.

Use was made of the normal engineering control lines to relay instructions for S.P.G. adjustments, etc. to the remote sites.

Experience prior to Transmission Day

The slavelock equipment was installed in St. Paul's on Wednesday, 27th January and was tested by locking local S.P.G.'s with fair success. Various unit faults were detected mainly associated with relay holder contacts.

Tests with the remote sites began on Thursday 28th. In several cases the 2Lf signal was not reaching the sites or was fluctuating in level on arrival. As the day progressed these line deficiencies were corrected and serviceability improved. Site 1 could not be locked however and this was found to be due to faulty receivers at both 1 and 1a due to

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power supplier unit faults. These were replaced (thus consuming all spares) and locking of 1, 1a and 1b was achieved.

By Friday 29th a good measure of success in locking the whole network was obtained and attention could be given to more minor deficiencies. Slight line twitching was visible on Site 5 (Eastcheap). This was thought to be due to interference clicks on the 2Lf line although the measured interference was quite low (-50dB). A higher sending level with attenuation at the distant end did not improve matters. For Saturday, transmission day, the Post Office changed the line and no further twitching occurred but this does not prove very much as the teleprinter activity was probably much less on that day and, in any case, the fault may have had some other cause.

Site 1 also showed occasional line twitches at times, not as frequent as at Site 5 but enough to give some concern. In this case it was decided to make a judgement on Saturday morning when interference would be lower as to whether to use the slavelock system or to let Sites 1, 1a and 1b operate independently.

Slavelock dropped out occasionally during Friday on Sites 6/6a but pulled in again each time within a few seconds. No cause was detected for these lapses.

The other sites behaved well and locked in with little or no trouble. Each day all S.P.G.'s were picture phased to St. Paul's to give operational practice to all concerned. As there were over 30 generators involved, this occupied quite a fair amount of time.

Results on Transmission Day

At 07.30 on transmission day all locking equipment was functioning well except that concerned with the Festival Hall (Site 9) where the vision line had been lost incoming. This site was switched to mains lock pending arrival of their signals.

Sites 5 and 1 showed no line twitching so it was decided to use slavelock in these cases.

All sources including the video tape reproduction (but except Festival Hall) were finally picture phased on both main and spare S.P.G.'s.

The programme on Saturday 30th January began at 09.20 with a comparatively quiet progression around all the different sites to set the scene before the procession proper began at 09.45.

During the preliminary round-up all was going well until some four minutes in when Site 1 lost slavelock suddenly whilst on transmission. After waiting some thirty seconds to see if lock would re-establish itself, without success, Site 1 was asked to switch over to mains lock and to continue with 1a and 1b independently. This was done, causing a momentary sync. disturbance and then things settled down again. Although wildly out of sync. with the reference pulses, it appears that the field rate of Site 1 during the unlocked period did not go more than about 0.3 cycles away from 50 cycles. No video tape or film recorder had any difficulty in holding onto the signal. The cause of the loss of slavelock was not discovered; 2LF was incoming to Site 1 throughout. Possibly an intermittent fault developed within the transmitter. Site 1 was later re-slavelocked without any difficulty.

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This trouble was made much more noticeable by the appearance on the St. Paul's picture output of unlocked 'ghost' syncs. This was due to break-through of 'reference' syncs onto the now non-sync Site 1 signal. The break-through was later found to be in the mixer almost certainly due to a fader control being just off its back stop. Sync crosstalk was thus always present but only became visible when the cut-up signal was non-sync. This shows another advantage of synchronous working - sync crosstalk becomes much less important.

The Festival Hall vision signal arrived shortly before transmission started but was rather erratic, so it was decided not to attempt slavelock for the preliminary round-up visit which was therefore taken picture phased only. The remainder of the round-up of sites was quite satisfactory from the synchronous point of view except the picture-phased Site 9 which showed faint sync ghosting.

It was decided to keep the Sites 1, 1a and 1b on local mains lock for the procession proper rather than risk a repetition of a sync disturbance during this critical opening part of the ceremony. Site 1 was therefore operated locally mains locked and 1a and 1b were slavelocked by Site 1. The trio were mixed synchronously in Site 1 mixer and all were picture phased to St. Paul's.

Some sync ghosting was visible on this signal, but was rather less visible than earlier, it being almost unnoticeable at this stage.

On cutting to Site 1b, further along the route, a very noticeable line twitching became apparent; this was of a similar form to that seen on the Friday on Sites 1 and 5 but was of a large amplitude. It was decided not to ask for Site 1b to change to local mains lock as this would have caused further disturbance and would also require cutting non-sync on the Site 1 mixer. So the line twitching continued, lastly unfortunately practically all the time that 1b was in use. Examination of the film recording shows that the displacements were only of the order of 3 micro-seconds, but they were very clearly visible and quite distracting.

During this time various cut-aways had been made to the 2a site for the firing of salute guns. 2a was, of course, only picture-phased but the intercuts were quite good. Drifting ghost syncs were visible on the 2a pictures.

After the Site 1 contribution was completed, all subsequent cuts were truly synchronous except, of course, those to the guns at 2a. The Festival Hall site was made slavelocked by the time it was used. Even during the ceremony in St. Paul's there were odd shots to the other sites outside to give atmosphere and the smoothness given to such inserts showed the value of synchronous working.

To remove any possibility of ghosting syncs from St. Paul's on the final video tape contribution, the master S.P.G. was itself genlocked to the video tape feed as soon as the mixer had cut to same. All the slaves lost lock momentarily but recovered within a second or two. Since no other source was to be used after the video tape item, this was of no consequence, but it was interesting to see that such a technique was practicable.

Review of Recordings

Parts of the recordings on video tape and 35 mm. film of this programme have been examined, particularly the first 40 minutes where Site 1 was involved. In both recording mediums there is a very noticeable improvement when the cuts are between truly synchronous sources, these showing no disturbance at all. Most of the vertical disturbances were corrected by picture phasing, although there was at least one frame roll of the film recording display on such a cut.

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A small but important vertical creep for several frames after the cut was visible on all these non-sync cuts, which significantly mars a film recording.

Even when picture phased there is a varying line phase error as the two mains holds swing to and fro. The change of line sync phase on cutting from one to the other causes a horizontal 'lurch' of the picture monitor or display tube when the line time-base is flywheeled. This is moderately objectionable and may last for a whole field. It breaks the smooth picture flow, confirming again that synchronous working is worthwhile.

The precise effect of a non-sync cut cannot be predicted, as it depends on the various locks and servos in recorders and monitors and the control settings thereof. As television equipment becomes more complex and sophisticated its sensitivity to previously tolerable conditions becomes increased.

Conclusions

Several conclusions can be drawn from this exercise, namely:

1. Synchronous working is definitely valuable and should be planned into multi-source programmes from the outset.

2. Even the best picture phasing is a poor substitute for true synchronism as line phase errors cause noticeable horizontal disturbance on cuts.

3. Cascaded slavelock and genlock/slavelock methods are practicable but are less flexible and reliable, so that single loop systems are definitely to be preferred operationally.

4. More thought should be given to methods of reverting to local lock in a smoother manner than is possible at present.

5. The use of auto-sync-sensing mixers would be very useful to cover against the occasional loss of lock whilst transmitting, yet preserving immaculate sync continuity at all other times.

6. More slavelock units are required if 100% locking is to be achieved on such epics in the future. Nine sets were available in O.Bs. and four were borrowed from Studios, and even this number was insufficient to cover all sources. The operation could not have even been attempted on 625-lines; there are so few units available. Decisions on numbers required are, of course, complicated by the coming of the alternative crystal-locked slavelock system now under development.

7. The slavelock technique used on this production was, broadly, that all locked sources were <u>continuously</u> locked. Some economy of slavelock transmitters is possible if less diversity is accepted, sources only being locked shortly before being transmitted. However, this prohibits the random-access so desired by producers and is operationally hazardous, at least at this stage of the art.

8. Further investigation should be made into the cause of the line twitching fault. Particular attention should be paid to the effect of interference on the 2LF line and, if necessary, a special performance specification drawn up for same, or the slavelock system made more tolerant of interference.

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9. The relay holders used in the slavelock transmitters and receivers were found to be extremely unreliable as regards making contact with the relay pins (some ten contact faults in a week). Their use should be discontinued immediately. The relays (60 LAA-1B) would be better soldered direct into circuit unless a much superior holder is substituted. The intermittent losses of lock could well have been due to these relay holders although this cannot be proved, of course.

10. A properly engineered slavelock control point should be devised probably based on the bay mounting type of unit construction, as used in Studios, rather than the O.B. "biscuit tin" style. Front entry cables cause much wiring confusion at the operating point. Ready monitoring of 2LF output should be provided. A horizontal "layering" principle - one level per source with all related units and facilities (transmitter, lights, preview, monitoring, control line, etc.) - would appear to be the best layout from the human engineering point of view.

Acknowledgements

Most of the operational slavelock and monitoring methods used on this production were the direct suggestions of R. Thomas (Assistant Investigations to S.E.Tel.S.& O.B.) who also carried out the onerous task of combining the two ten-channel mixers into one.

Excellent co-operation and assistance were given by D. Crowland, J.D. Hughes and F.S. Snape, of Tel.O.Bs., in the construction, installation and operation of the slavelock equipment.

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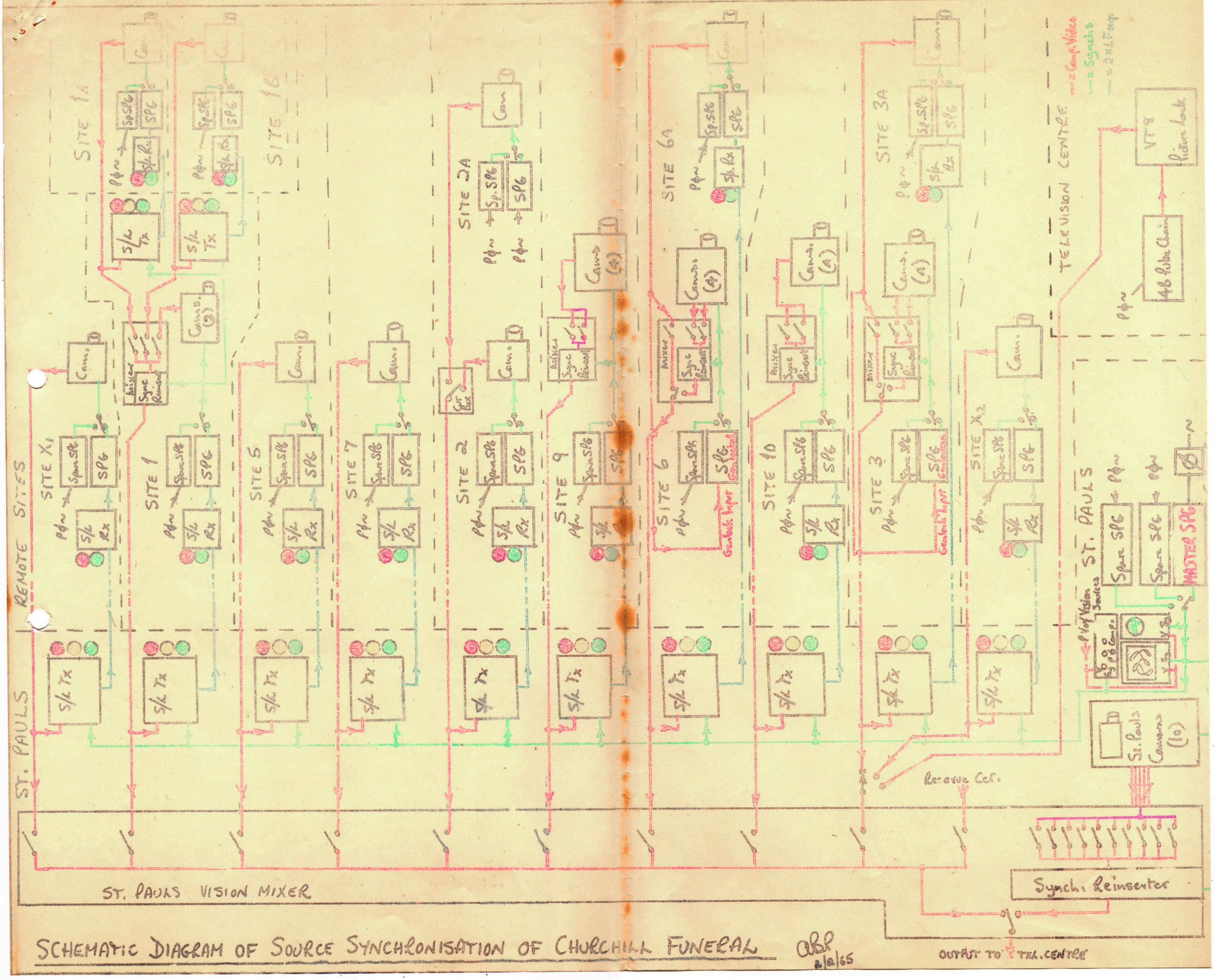

SCHEMATIC DIAGRAM OF SOURCE SYNCHRONISATION OF CHURCHILL FUNERAL

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