REAL TIME SYNCHRONIZATION VIA PASSIVE TELEVISION TRANSMISSION

by

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1.0 ABSTRACT/INTRODUCTION

A method to utilize television transmission in a passive mode for the real time synchronization of clocks has been developed and is presented herewith.

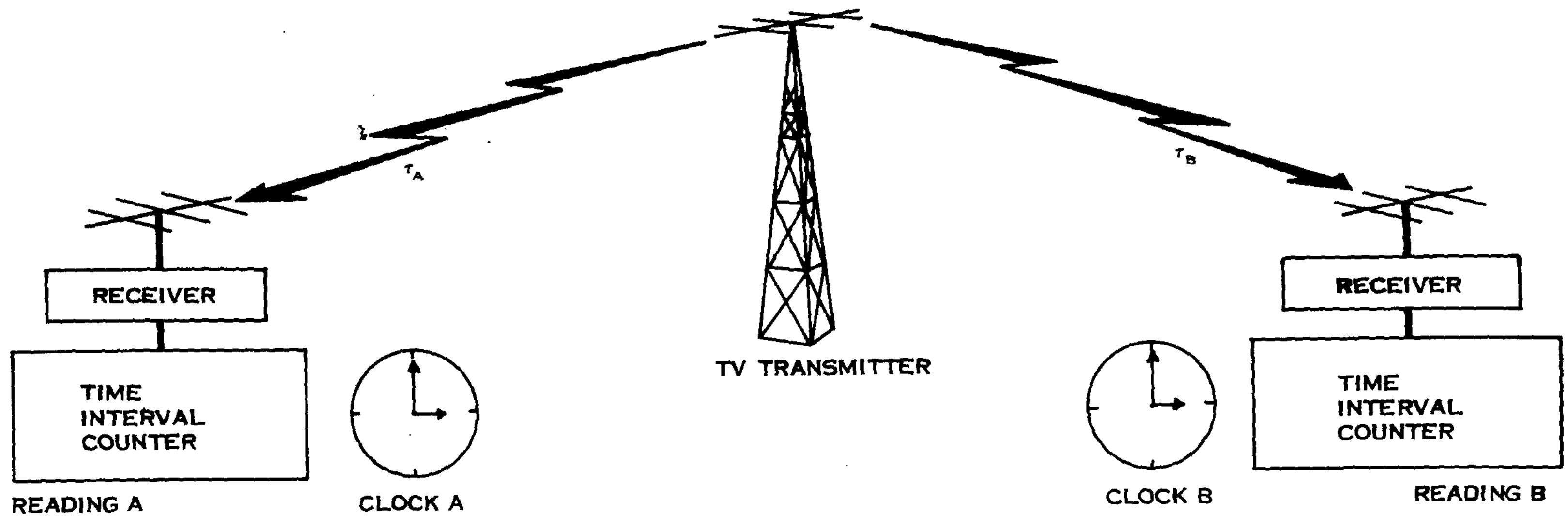
A demonstration is currently being conducted in Washington, D.C. to show that the time of day referenced to the U.S. Naval Observatory (USNO) Master Clock (MC) can be derived independently by timing stations monitoring the transmission from the local TV station WTTG (Channel 5). The accuracy and precision that can be achieved with this method is in the submicrosecond region.

2.0 BACKGROUND

2.1 Passive System for Differential Time Transfer

A passive method using television transmission for precise clock time comparisons was first conceived and demonstrated in Europe by an experiment conducted in November 1965.[1] Since then, this method

[1] Tolman, J., V. Ptacek, A. Soucek, and R. Stecher, (1967), "Microsecond Clock Comparison by Means of TV Synchronizing Pulses," IEEE Transactions on Instrumentation and Measurement, Volume IM-16, No.3, September 1967, pp. 247-254.



$$\left[\text{CLOCK A} - \text{CLOCK B}\right] = \left[\text{READING A} - \text{READING B}\right] - \left[\tau_A - \tau_B\right]$$

NOTE READING A AND READING B ARE THE TIMES OF ARRIVAL OF THE SAME RECEIVED VIDEO PORTION (LINE) READ SIMULTANEOUSLY AGAINST THE RESPECTIVE CLOCKS.

Figure 1. "PASSIVE" SYSTEM FOR DIFFERENTIAL TIME TRANSFER (EUROPEAN SYSTEM)

has been widely used in some European countries and with some success in the U.S.A. to monitor time differences between clocks located in various laboratories.[2,3,4]

The method consists of recognizing and identifying a portion of a video transmission as a time marker (line 10 is used in the U.S.) and of measuring its time of arrival simultaneously at remote locations using precise clocks. Successive differential measurements against the participating clocks will give a measure of the time divergence of the clocks.

The fact that the circuit and propagation delays have submicrosecond stability and that the TV time marker can be defined with nanosecond resolution permits relative time transfer measurements to be made with submicrosecond precision.

In this passive system, relative time transfers can be made provided that:

- Readings are taken simultaneously.
- Readings are exchanged after the fact between monitoring clocks.

2.2 Active System for Real Time Transfer

Another approach for precise time transfer via television transmissions was demonstrated in 1970 by the U.S. National Bureau of Standards.[5] This method consisted of actually transmitting time information

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[2] Parcelier, P., (1969), "Developpement des synchronisations de temps par la television," Proceedings Internat. Conf. Chrommetry (Paris), Series A-26, 16-20 September 1969, pp. 1-6.

[3] Parcelier, P. (1970), "Time Synchronization by Television," 1970 Conference on Precision Electromagnetic Measurement, IEEE Transactions on Instrumentation and Measurement, Volume IM-19, No. 4, November 1970, pp. 233-238.

[4] Davis, D.D., Bryon E. Blair, and James F. Barnaba, (1971), "Long-Term Continental U.S. Timing System via Television Networks," IEEE Spectrum, August 1971, pp. 41-52.

[5] Koide, F.K. and E.J. Vignone, (1971), "TV Time Synchronization in the Western U.S.," EID-Electronic Instrumentation, October 1971, pp. 26-31.

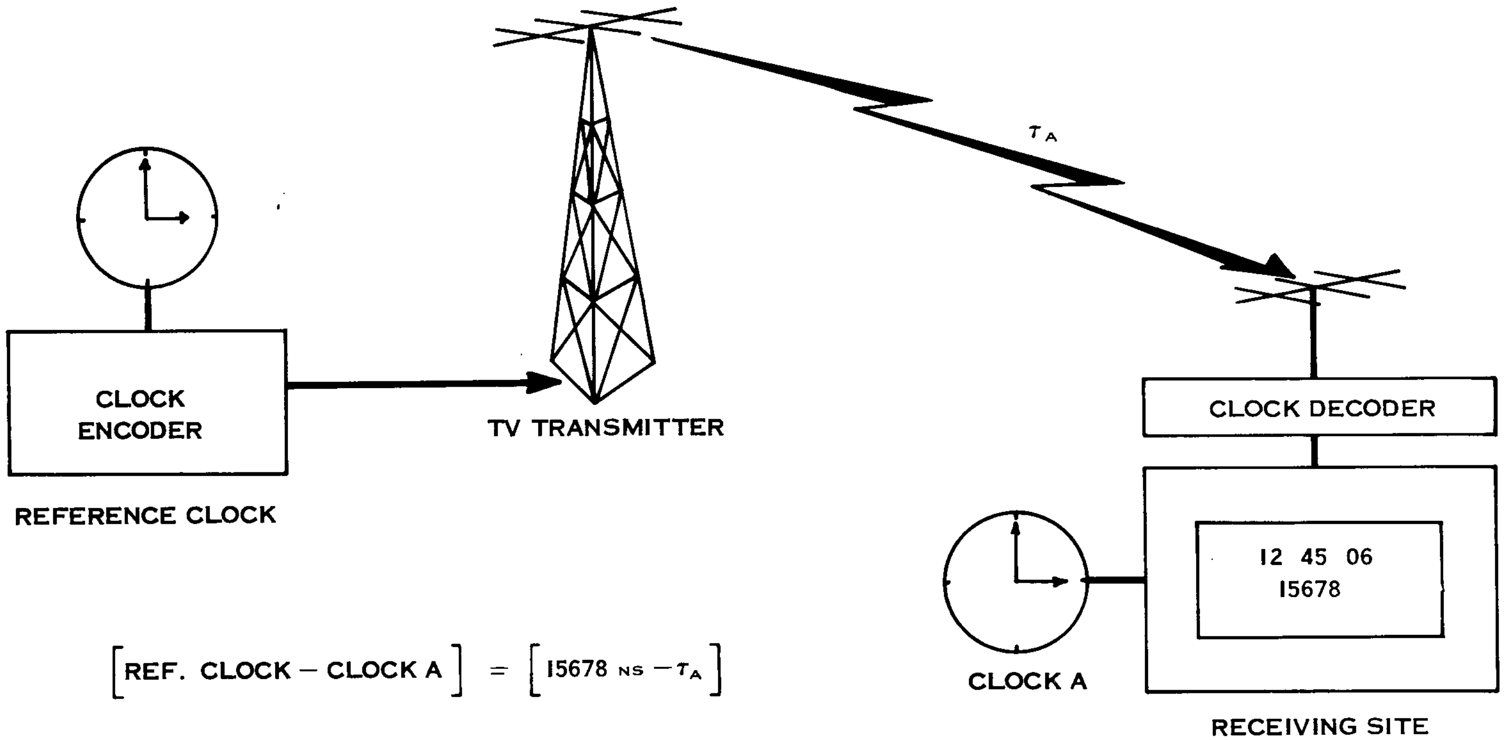

Figure 2. "ACTIVE" SYSTEM FOR REAL TIME TRANSFER (NBS LINE 16 AND 1 SYSTEM)

via the television media. For that purpose, a precise clock and clock encoder were located at the TV transmitter and clock decoders and television receivers were placed at remote locations where precise time transfers were to be made.

In this active system, real time transfers can be made provided that:

- Clock and clock encoder are available at the TV transmitter.
- Clock decoders are placed at time monitoring sites.
- Actual time transmissions are secured.
  - A "portion" of the video transmission must be available for insertion of the time information.
  - FCC authorization is required.

3.0 DESCRIPTION OF THE REAL TIME SYNCHRONIZATION TRANSFER METHOD

A passive method for real time transfer via television transmissions has been conceived and proposed by the USNO. This method can be used to set clocks at remote locations, independently, and in an absolute sense, to within a few nanoseconds of a reference clock.

The technique consists of time positioning the video transmissions from a TV station such that certain television horizontal pulses are transmitted in synchronization with particular seconds of a UTC scale referenced to the U.S. Naval Observatory Master Clock.

By stabilizing the 3.579545 megahertz TV color subcarrier frequency of a TV transmitter and by phase shifting it, it is possible to synchronize the TV transmissions by forcing a coincidence between an emitted horizontal line (line 10 odd was selected as a reference time marker to keep it compatible with existing receiving equipment) and a one-second pulse from a reference clock (the USNO MC itself was selected for this purpose). This subcarrier frequency is also used to maintain proper timing of the horizontal and vertical pulses.

Because of the unique TV frame repetition rate, this coincidence for the U.S. television system (33.36666666...ms), will occur every 1001 seconds exactly (16^M 41^S). By establishing an arbitrary time of coincidence, it is possible to calculate the dates (times) at which subsequent coincidences will occur between one pulse per second time marks from the USNO Master Clock and the emitted odd horizontal line 10. Such times of coincidence have been computed by assuming an initial coincidence at 0000 UT 1 January 1958 and are given for the second half of the year 1971 in the appendix as "Time of Coincidence (TOC) Ephemeris Reference Tables for Television Transmissions Synchronized to the USNO Master Clock." These tables have the same format as those presently used for Loran-C. Table 1* gives the first TV line 10 odd TOC for each day in hours, minutes, and seconds. Table 2 gives all relative TOC's in a day -- in hours, minutes, and seconds. By adding the relative TOC's (Table 2) to the first TOC of any day (Table 1), one obtains the absolute TOC's for that day. Table 3 gives the time differences for every second of the time interval between the relative TOC's of Table 2 (1001 seconds) and the subsequent TV odd line 10 pulse.

A clock located near a local television stations, whose transmissions are disciplined to the USNO Master Clock, can be set to or accurately measured against the reference clock by using the TOC tables. The procedure involved is similar to the one used for the synchronization of clocks via the Loran-C system.

- A knowledge of the geographical location of the clock relative to the TV transmitting antenna is necessary in order to compute the propagation time delay. This delay can also be determined initially by transport of clocks.

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* Tables 1, 2 and 3 are located in the appendix.

- The clock time must be set or known to within 16 milliseconds (half of the TV frame period). This can be done by using the HF standard time signal transmissions from CHU, WWV, NSS, etc.

Using the receiving system shown in Figure 3, the procedure listed below should be followed:

1. Take a series of measurements during a synchronized period of TV transmissions, recording:
   (a) The time differences between the one-second pulse from the local clock and the received horizontal line 10 odd pulse (output of the line 10 pulse discriminator).
   (b) The dates (times) at which those readings are taken.
2. Using the TOC tables (see appendix), reduce the data as shown in the example below:

   Example: Let the local clock be a clock (Clock A) located at a monitoring station A. Suppose measurements are taken on 21 October 1971.

   (a) From the measurements: (e.g., as printed by a line printer)

Hr.	Min.	Sec.	μs
16	51	17	9121.25
16	51	16	8121.24
16	51	15	7121.26
16	51	14	6121.25
16	51	13	5121.25

   (b) From the TOC Tables:

From Table 1		$0^H \ 11^M \ 48^S$
From Table 2	+	$16^H \ 24^M \ 19^S$
Time of last coincidence:		$16^H \ 36^M \ 7^S$

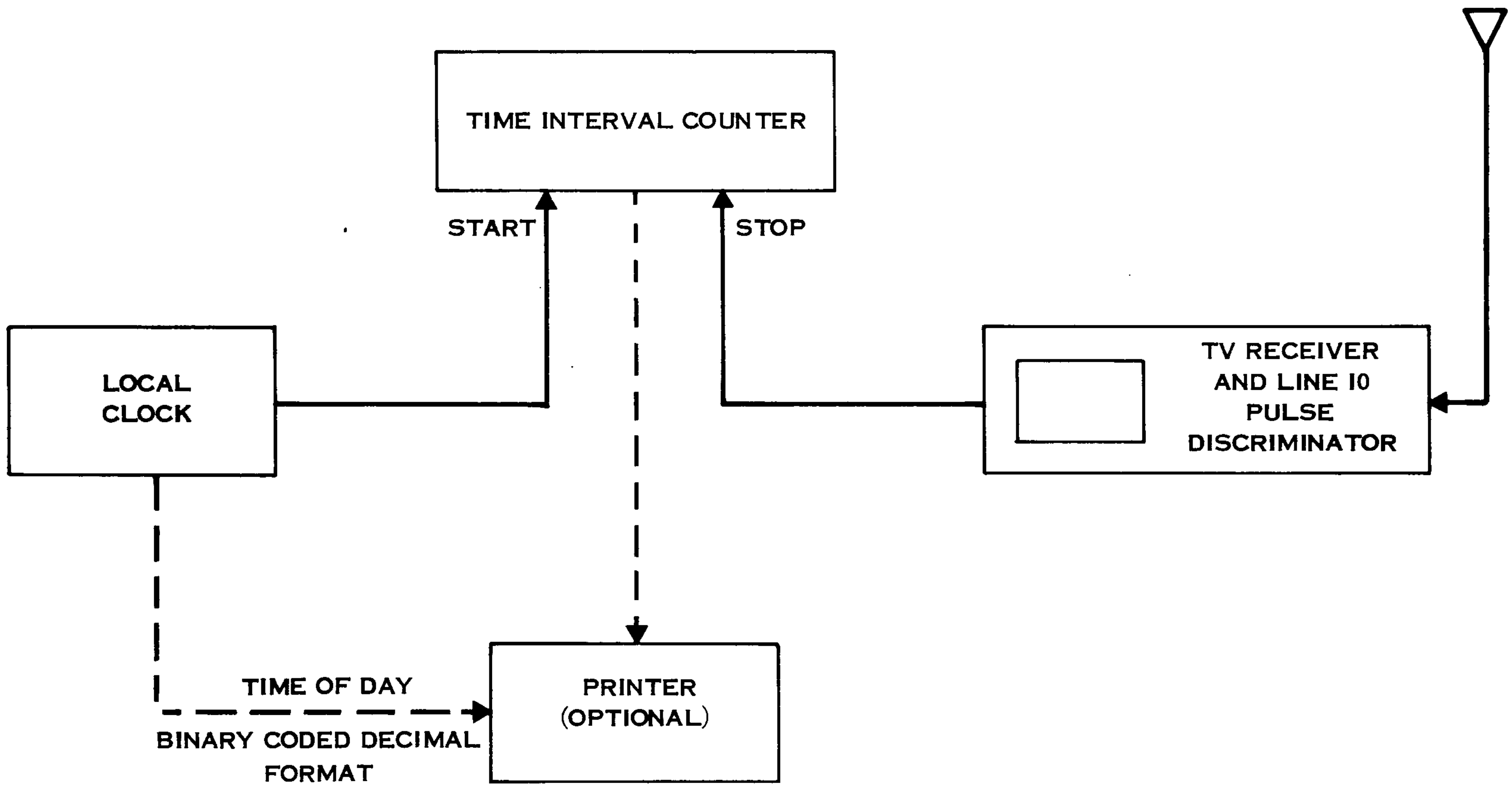

Figure 3. RECEIVING SYSTEM FOR TV TIME TRANSFER

Selecting arbitrarily the measurement taken at $16^{H}\ 51^{M}\ 14^{S}$, one calculates the time which has elapsed between that measurement and the last coincidence:

$$\begin{array}{rrrr} & 16^{H} & 51^{M} & 14^{S} \\ - & 16^{H} & 36^{M} & 7^{S} \\ \hline & & 15^{M} & 7^{S} \end{array}$$

(c) From Table 3 one finds that $15^{M}\ 7^{S}$ corresponds to 6,100.000 μs.

This means that the first horizontal line 10 odd pulse following $16^{H}\ 51^{M}\ 14^{S}$ was transmitted on 21 October 1971 at $16^{H}\ 51^{M}\ 14^{S}.006100000$, (or 6,100.000 μs after the 14th second). That very same horizontal line was received at $16^{H}\ 51^{M}\ 14^{S}.00612125$ (or 6,121.25 μs after the 14th second).

Assume that the propagation time for the path between the transmitting antenna of the TV station and the TV receiving antenna at the Monitoring Station A is 18.00 μs. One finds, by subtraction, that Clock A was in error with respect to the TV transmissions by:

$(6121.25\,\mu s - 18.00\,\mu s) - 6100.00\,\mu s = 3.25\,\mu s$.

This can be expressed as follows:

At 1651 UT 21 October 1971, UTC (Clock A) - UTC (TV) = 3.25 s.

4.0 EXPERIMENT

On 23 September 1971, the U.S. Naval Observatory installed an instrumentation systems, which was conceived and assembled at the Observatory, in the master TV control room of the local Metromedia station WTTG (Channel 5). A cesium portable clock set to the USNO Master Clock was carried to the TV studio at this time.

This system was set up as shown in Figure 4. All instruments were connected to a 24-hour service powér source. The digital clock was synchronized to the USNO MC via the cesium portable clock. The 3.579545 megahertz frequency output of the synthesizer was phase shifted so that the time difference between the 1 pps from the digital clock and the emitted horizontal line 10 odd pulse output of the TV discriminator agreed with the values listed in the TV TOC tables (see appendix).

The video transmissions, thus synchronized at the TV studio by using the TOC tables, were checked at the U.S. Naval Observatory by measuring the time of arrival of the same horizontal line. No attempt was made at that time to accurately set the video emissions from WTTG to the U.S. Naval Observatory Master Clock. This could have been done by applying necessary corrections for all instrumentation delays.

The daily time differences between the USNO Master Clock and the WTTG emitted horizontal line 10 (odd frame) are listed in Table I and plotted in Figure 5. Some daily measurements were made during live transmissions and others during film transmissions. Transmitter delays were measured to vary by about 0.5 microsecond when programs were switched between those two sources. This and the fact that daily measurements recorded were not from averaged readings, accounts for the large variations shown on the graph (Figure 5). Precautions can easily be taken during measurements to prevent this from happening. The path delay at the transmitter, between the oscillator and the transmitting antenna will be kept constant by using the automatic line of instrumentation proposed below.

Note: The oscillator was free running during the period of the experiment. No corrections were applied to the phase of the 3.57945 megahertz synthesized frequency nor were any corrections applied to the frequency or the phase of the oscillator.

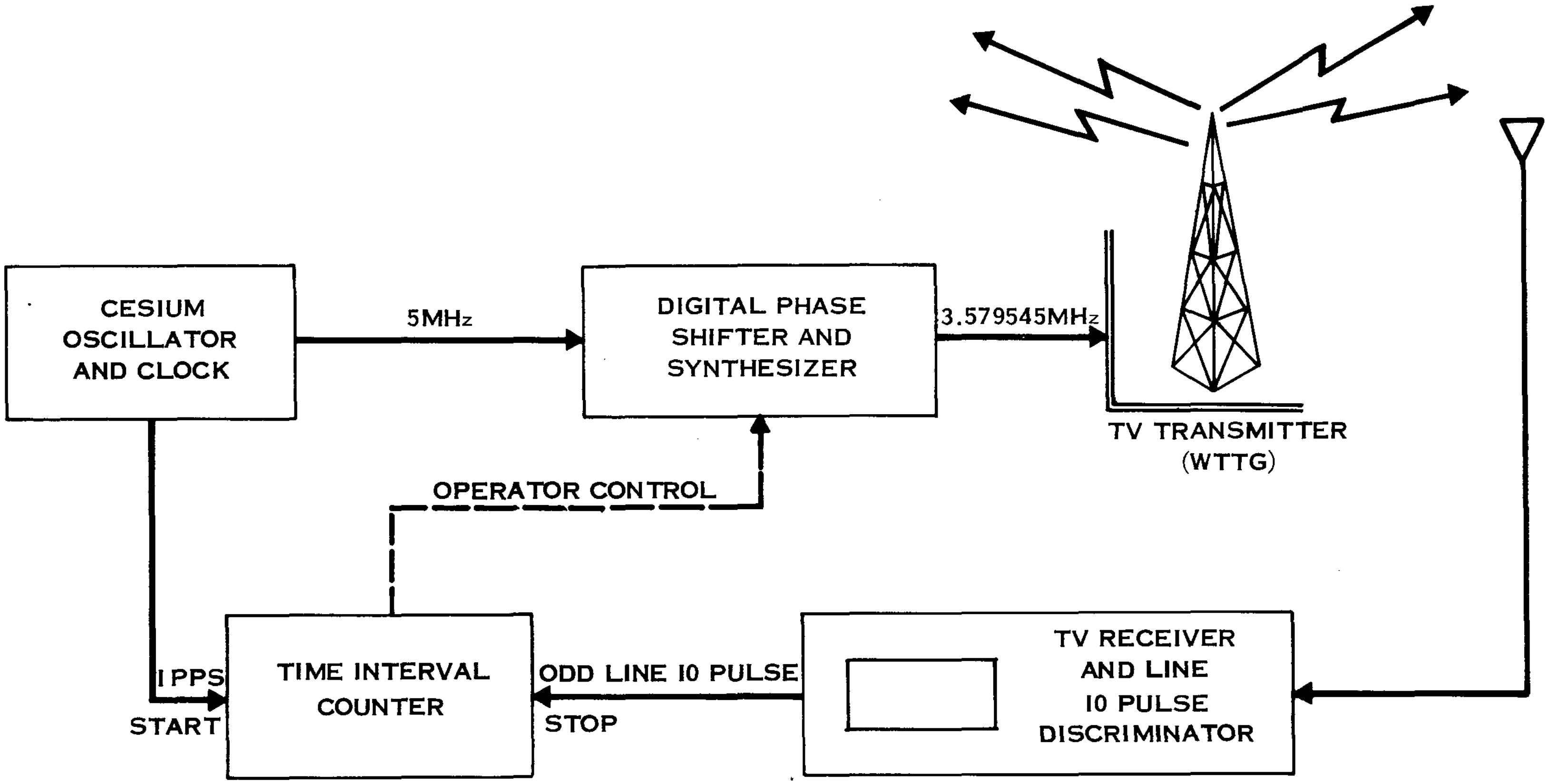

Figure 4. EQUIPMENT INSTALLED AT THE TV TRANSMITTER FOR THE EXPERIMENT

Table I. DAILY TIME DIFFERENCES
UTC (USNO MC) - UTC (WTTG)*

DATE 1971	UTC (USNO MC) - UTC (WTTG) *
SEPTEMBER 28	3.22 μs
29	3.15
30	3.18
OCTOBER 1	3.18
2	
3	
4	3.80
5	3.65
6	3.24
7	3.60
8	3.13
9	
10	
11	
12	3.00
13	2.86
14	2.80
15	2.82
16	
17	
18	2.86
19	2.84
20	2.72
21	2.71
22	2.71
23	
24	
25	
26	2.69
27	2.63
28	2.10
29	2.56
30	
31	
NOVEMBER 1	2.73
2	2.63
3	2.49
4	2.48
5	2.24
6	
7	

* UTC (WTTG) is the emitted odd horizontal line 10 of phase controlled transmissions from WTTG.

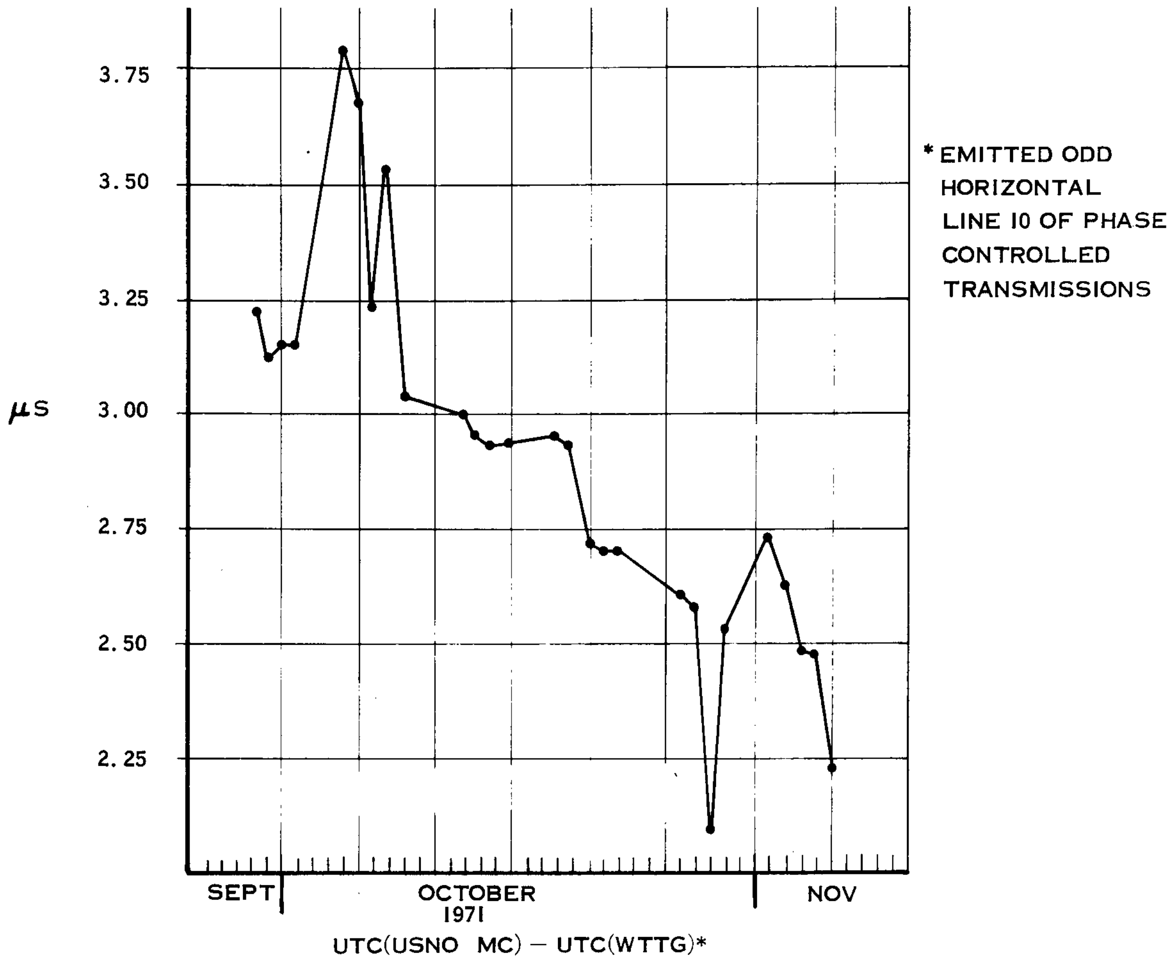

Figure 5. EMITTED ODD HORIZONTAL LINE 10 OF PHASE-CONTROLLED TRANSMISSIONS FROM WTTG VERSUS THE U.S. NAVAL OBSERVATORY MASTER CLOCK

5.0 EQUIPMENT USED FOR THE EXPERIMENT

5.1 TV Transmitter (WTTG)

The equipment installed by the USNO in the WTTG TV control room consists of a cesium oscillator and digital clock, a digital phase shifter and TV subcarrier frequency synthesizer, a time interval counter, and a TV receiver and line 10 pulse discriminator (see Figure 6).

The five megahertz output of the cesium oscillator is connected to the input of the synthesizer and digital phase shifter unit which generates the 3.579545 megahertz color subcarrier frequency for the TV transmitter. The TV receiver and line 10 pulse discriminator monitor the TV transmissions and generate a pulse every odd horizontal line 10 transmitted. This pulse is compared every second to the output of the clock on the time interval counter.

A completely automatic line of instrumentation could be developed for use at the TV transmitter. Presently, by using the system installed by the USNO, approximately 50 percent of all transmissions from WTTG are phase-controlled, such that the video is transmitted on time with respect to the USNO MC by positioning line 10 as explained above. That percentage could be increased substantially, however, by installing in the TV studio a phase shifter which could automatically correct the phase of the subcarrier frequency when video transmissions step away from the synchronized position. Certain sources of programs will generate this condition. A prototype for an automatic phase detector, phase shifter, and video positioner is presently being developed and should be evaluated in the next few months.

5.2 Monitoring Site (U.S. Naval Observatory)

The instrumentation system at the USNO consists of a TV receiver and line 10 pulse discriminator, a time interval counter, and a

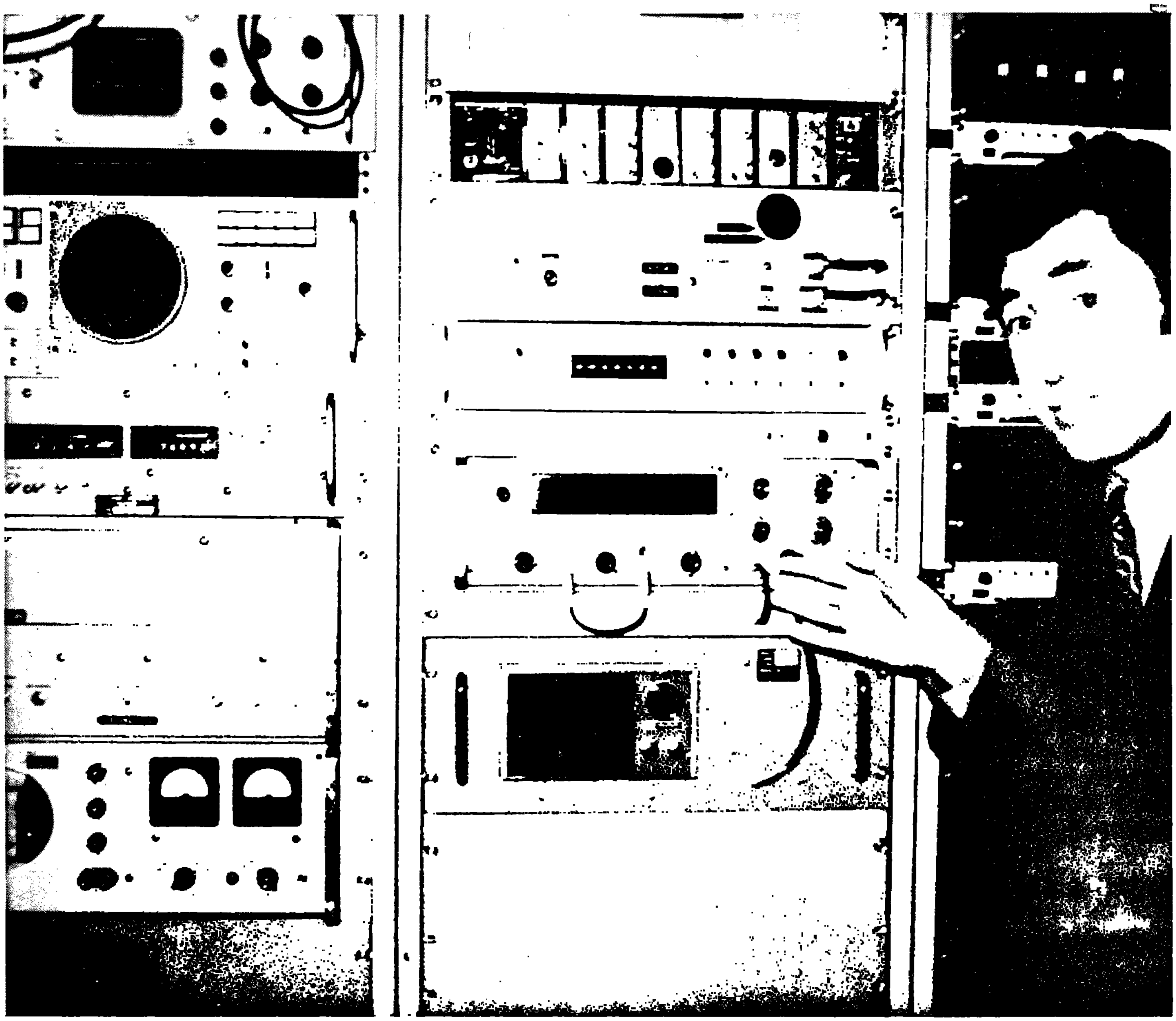

Figure 6. EQUIPMENT AT TELEVISION TRANSMITTING STUDIO

printer. The TV receiver and line 10 pulse discriminator monitors the TV transmissions and generates a pulse every odd horizontal line 10 received. This pulse can be compared at any second to the output of the USNO Master Clock and the time of arrival of this TV reference pulse is read on the time interval counter (see Figure 7).

Similarly, improved TV time receiving systems can be built to give a direct presentation of the time difference in microseconds between a local clock and a "TV transmitter clock." This can be done by compensating for the propagation delays and by normalizing one of the clocks to the other, such that their respective time marks can be compared on a time interval counter to give an actual display of the time difference between the two clocks. A prototype of such an apparatus is also being developed for evaluation.

6.0 CONTROL OF TRANSMISSIONS BY A REFERENCE CLOCK

The correct time position of the video transmissions can be secured by a monitor station having the reference clock for the system. In the Washington, D.C. area, the USNO is that control station and the reference clock to the TV transmitter is the USNO Master Clock (see Figure 8).

As long as the clock and phase control equipment installed at the TV station performs normally, the only parameter which may have to be adjusted is the frequency of the oscillator located at the TV studio. The effective frequency of this oscillator must be the same as the frequency of the reference clock (USNO MC). Any frequency offset of the TV oscillator from this clock will cause the position of the video transmissions to shift slowly away from it. A time agreement between the TV and USNO clocks can be secured by issuing to the station minute periodic phase step corrections which will be computed at the USNO. This could be accomplished automatically by installing at the TV studio a programmable microphase stepper, the rate of which will be controlled by the USNO (see

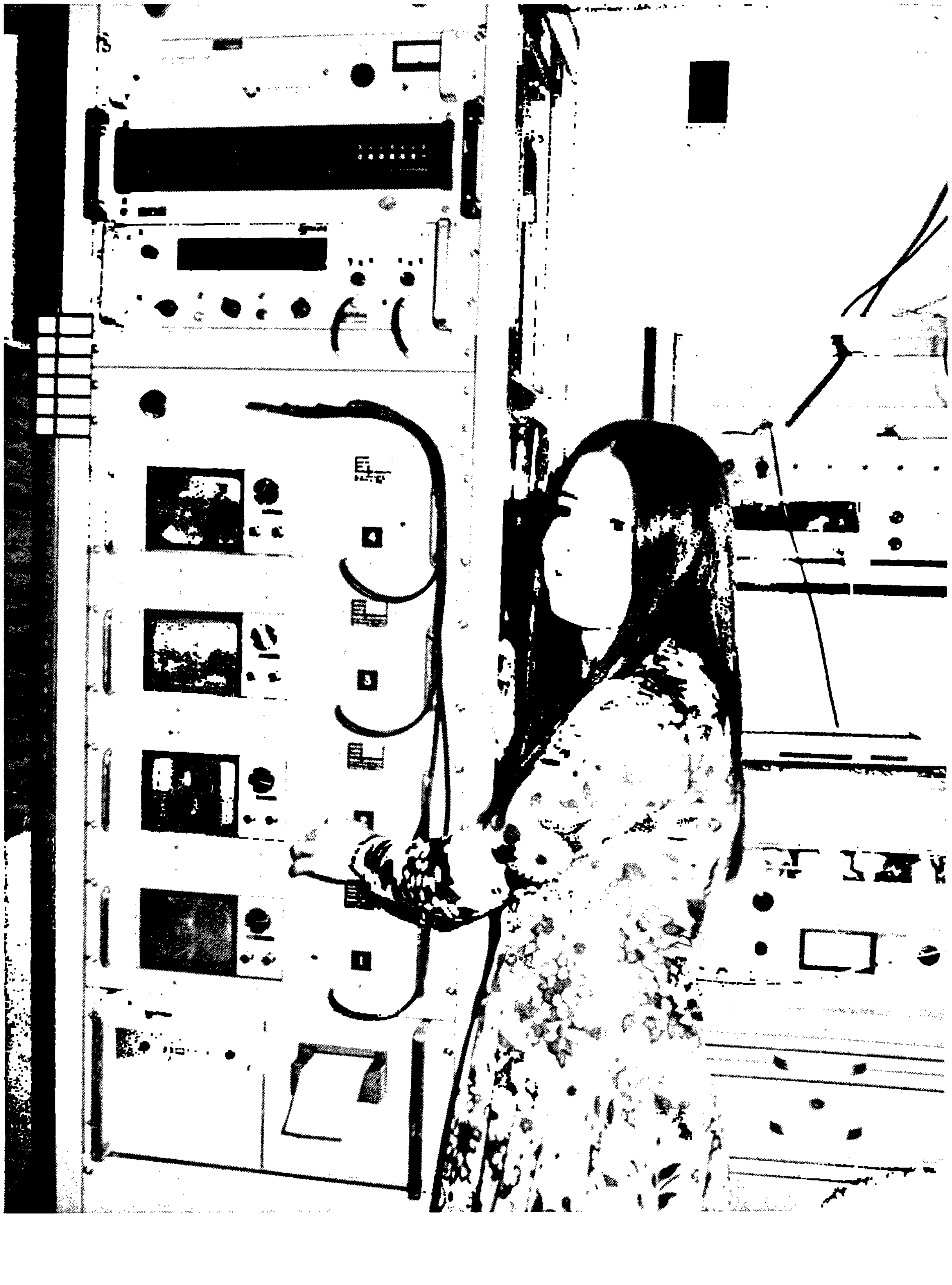

Figure 7. TIME MONITORING RECEIVING SYSTEM

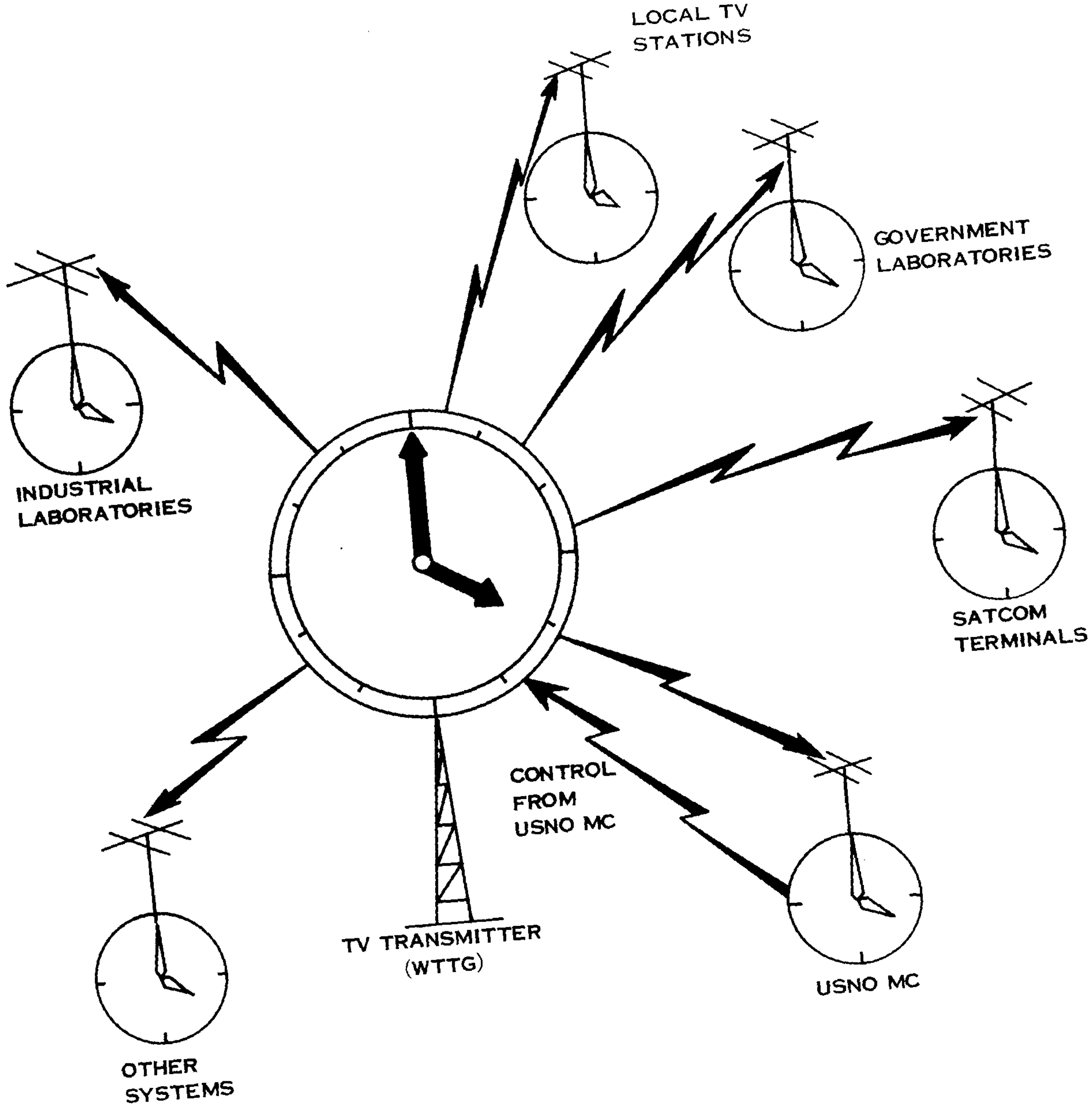

Figure 8. DISTRIBUTION SYSTEM AND CONTROL

Figure 9). Incidentally, such an apparatus is commercially available to give programmable phase corrections at an average rate as small as ten femtoseconds/sec (0.000000010 microseconds/sec). Also, a "disciplined oscillator" could replace the cesium oscillator installed at the TV studio, thus effecting a consequent cost reduction.

7.0 EXTENDED COVERAGE

Any timing system located within the reception area of time-controlled TV transmissions emitted from a local TV station can, of course, be synchronized using the method described above.

A large number of time-controlled TV transmissions could be set up over the continental United States simply by installing at the TV transmitter similar types of equipment as shown in Figure 9. The major problem would be to keep all clock systems installed at the TV studios on time and on frequency with the reference clock. However, this could be implemented in many cases by the stations linking together (line-of-sight or microwave link) to keep their local oscillator and clock synchronized to each other, or by installing precise time standards which could be "visited" periodically to keep the offset (time and frequency) within acceptable limits. These "visits" could be done by portable clocks, fly-over techniques, satellite time transfers, Loran-C, and others.

It is possible and could be proposed to link the East Coast and West Coast U.S. TV stations to the USNO Master Clock via the SATCOM system. Time transfer with submicrosecond accuracy is presently and routinely being done between the SATCOM terminals located in Brandywine, Maryland; Camp Roberts, California; and others. Since the USNO has access to this SATCOM network through the Brandywine terminal, the system could be configured as shown in Figure 10. Selected TV stations located in Guam, Hawaii, the Philippines, Alaska, etc. could be linked to the USNO Master Clock simply and economically by using the same approach.

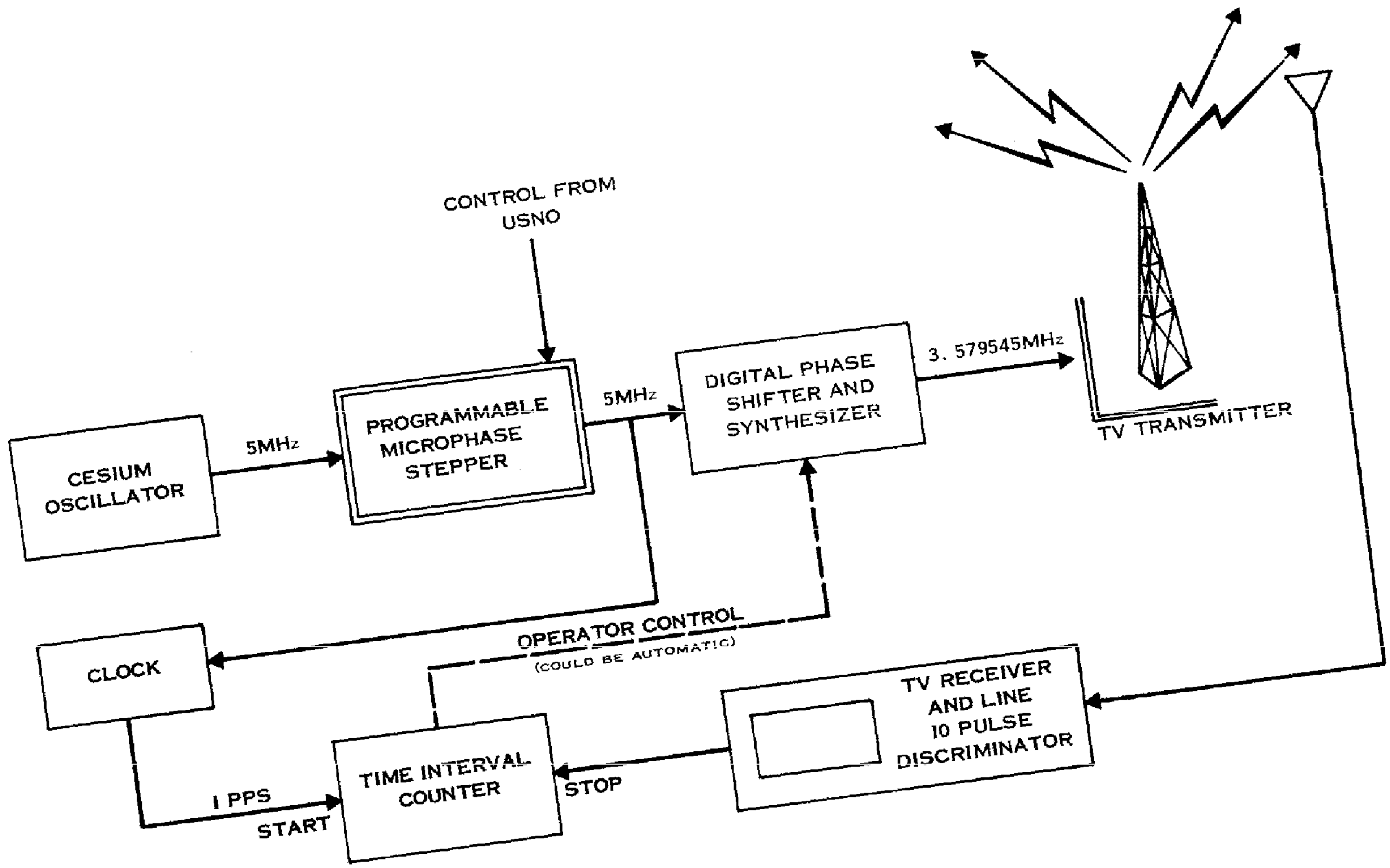

Figure 9. PROGRAMMABLE MICROPHASE STEPPER AT TV STUDIO

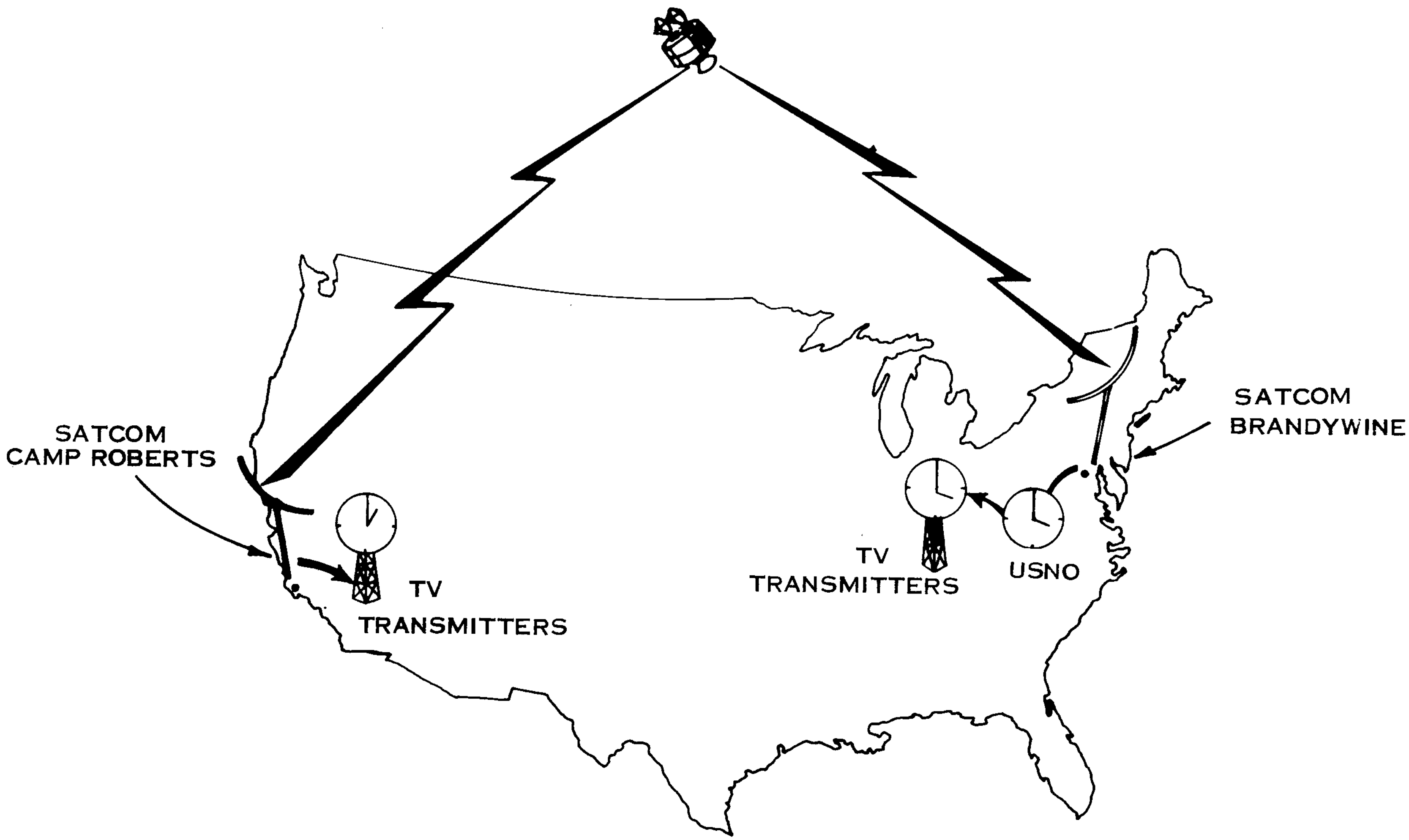

Figure 10. EXTENDED COVERAGE - LINKING EAST AND WEST COAST BY SATCOM SYSTEM

8.0 APPLICATIONS

Numerous applications could be found and implemented if accurate time and frequency could be obtained easily and inexpensively from the transmissions of existing TV stations. This could be the case, if the method of video phase-control described were to be used to discipline key TV transmissions.

Some of these applications could certainly be found in the fields of precise navigation, traffic control and transportation, collision avoidance systems, real time computer systems, geodesy, the TV industry, and high speed communications, just to name a few.

9.0 CONCLUSION

The method presented herein introduces a new approach to the use of existing television transmissions for PTTI applications. It is a system which:

- Permits real time transfer to be made independently to sub-microsecond accuracy
- Does not require any special TV transmissions (channel capacity)
- Improves stability of TV emissions
- Does not require special licensing
- Is simple to use
- Could be developed into the most economical system available for real time applications
- Is compatible with existing receiving equipment

A summary of the characteristics of the three TV transfer methods is discussed in Figure 11.

10.0 ACKNOWLEDGMENT

The authors wish to express their gratitude to the personnel of the WTTG Metromedia television station and, in particular, to Albert Harmon

"PASSIVE" SYSTEM FOR DIFFERENTIAL TIME TRANSFER

(EUROPEAN SYSTEM)
IN USE IN EUROPE AND IN THE USA

REQUIREMENTS:

- READINGS MUST BE TAKEN SIMULTANEOUSLY BY THE TIMING STATIONS TO BE SYNCHRONIZED.
- DATA MUST BE EXCHANGED AFTER THE FACT BETWEEN THE MONITORING STATIONS.
- LINE 10 PULSE DISCRIMINATOR MUST BE INSTALLED AT TIME MONITORING STATIONS.
- PROPAGATION AND EQUIPMENT DELAYS MUST BE KNOWN FOR ALL COOPERATING STATIONS.

CAPABILITIES:

- PERMITS DIFFERENTIAL TIME SYNCHRONIZATION TO SUBMICROSECOND PRECISION.

"ACTIVE" SYSTEM FOR REAL TIME TRANSFER

(NBS LINE 16 OR 1)
PROPOSED AND TESTED

REQUIREMENTS:

- CLOCK AND CLOCK ENCODER MUST BE INSTALLED AT TV TRANSMITTER.
- FCC AUTHORIZATION TO TRANSMIT IS REQUIRED.
- ACTUAL TIME INFORMATION MUST BE TRANSMITTED.
- TV RECEIVER MUST BE INSTALLED AT TIME MONITOR STATION.
- CLOCK DECODER MUST BE INSTALLED AT TIME MONITOR STATION.

CAPABILITIES:

- PERMITS REAL TIME TRANSFER TO SUBMICROSECOND ACCURACY.
- GIVES HOURS, MINUTES AND SECONDS IN ADDITION TO SYNCHRONIZATION.

"PASSIVE" SYSTEM FOR REAL TIME TRANSFER

(USNO SYSTEM)
PROPOSED AND TESTED

REQUIREMENTS:

- CLOCK AND PHASE SHIFTING SYNTHESIZER MUST BE INSTALLED AT TV TRANSMITTER.
- LINE 10 PULSE DISCRIMINATOR MUST BE INSTALLED AT TIME MONITOR STATION.

CAPABILITIES:

- PERMITS REAL TIME TRANSFER TO SUBMICROSECOND ACCURACY.
- PERMITS USE OF EXISTING "LINE 10" RECEIVERS.
- CAN BE IMPLEMENTED ANYWHERE WITHOUT SPECIAL LICENSING.

Figure 11. COMPARISON OF TV TIME TRANSFER METHODS

and Robert Swartwout for their cooperation and helpfulness throughout the experiment. They also wish to thank Austron, Tracor, and Timing Systems, Inc. for their help with the equipment. Thanks are also due to many colleagues at the USNO, in particular, to James McDermott for his assistance in preparing the instrumentation.

11.0 ADDITIONAL REFERENCES

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APPENDIX

26 August 1971

Time of Coincidence (TOC) ephemeris Reference tables for Television Transmissions synchronized to the USNO Master Clock.

1. INTRODUCTION:

Some Video transmissions are time positioned such that certain Television horizontal pulses - identified as line 10 odd - are transmitted in synchronization with particular seconds of a UTC scale referenced to the U. S. Naval Observatory Master Clock.

2. DISCUSSION:

The times of coincidence of TV line 10 odd pulses with second pulses of the U. S. Naval Observatory Master Clock are found for each day by adding the values given in Table 2 to the values given in Table 1.

Table 1 gives the first TV line 10 odd TOC for each day in hours, minutes and seconds.

Table 2 gives all relative TOC's in a day in hours, minutes and seconds.

By adding the relative TOC's (Table 2) to the first TOC of any selected day (Table 1) one obtains the absolute TOC's for the day.

Example 1:

Assume that an operator monitoring a Television transmission desires to make a synchronization check between the station clock and the TV synchronized transmissions at about 1930 UT 19 September 1971.

From Table 2, the values near 1930 UT are:

H	M	S
19	11	09
19	27	50
19	44	31

These values added to the value from Table 1 listed for the 19 September 1971:

H	M	S
00	12	26

give the times of coincidence between the beginning of TV line 10 odd pulses and U. S. Naval Observatory Master Clock one-pulse-per-second, namely:

H	M	S
19	23	35
19	40	16
19	56	57

Table 3 gives the time differences between every second of the time interval between the relative TOC's of Table 2 (1001 seconds) and the subsequent TV line 10 odd pulse.

Between the times of coincidence as given by Tables 1 and 2, the time difference between any one-pulse-per-second of the U. S. Naval Observatory Master Clock and the immediately following line 10 odd pulse of a synchronized TV transmission can be determined by using Table 3.

Example 2:

Assume that such a time difference is required at $19^h\ 30^m\ 00^s$ UT on 19 September 1971. For Tables 1 and 2 we found that the last TOC occurred at $19^h\ 23^m\ 35^s$ (see example 1). Therefore, the time at which the time measurement is required occurs 6M 25 sec after that last TOC.

From Table 3 we note that the value corresponding to 6 minutes 25 seconds is 17966.667 microseconds. Therefore, the TV line 10 odd pulse immediately following the $19^h\ 30^m\ 00^s$ UT one-pulse-per-second of the U. S. Naval Observatory Master Clock on 19 September 1971 will be transmitted at $19^h\ 30^m$ 0.017966667 sec.

UNCLASSIFIED

TABLE 1

FIRST TOC FOR EACH DAY

TIMES OF COINCIDENCE (NULL) EPHEMERIS
TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

DATE 1971	TIME H	M	S	DATE 1971	TIME H	M	S	DATE 1971	TIME H	M	S
OCT 1	0	16	22	NOV 1	0	4	17	DEC 1	0	14	7
2	0	11	8	2	0	15	44	2	0	8	53
3	0	5	54	3	0	10	30	3	0	3	39
4	0	0	40	4	0	5	16	4	0	15	6
5	0	12	7	5	0	0	2	5	0	9	52
6	0	6	53	6	0	11	29	6	0	4	38
7	0	1	39	7	0	6	15	7	0	16	5
8	0	13	6	8	0	1	1	8	0	10	51
9	0	7	52	9	0	12	28	9	0	5	37
10	0	2	38	10	0	7	14	10	0	0	23
11	0	14	5	11	0	2	0	11	0	11	50
12	0	8	51	12	0	13	27	12	0	6	36
13	0	3	37	13	0	8	13	13	0	1	22
14	0	15	4	14	0	2	59	14	0	12	49
15	0	9	50	15	0	14	26	15	0	7	35
16	0	4	36	16	0	9	12	16	0	2	21
17	0	16	3	17	0	3	58	17	0	13	48
18	0	10	49	18	0	15	25	18	0	8	34
19	0	5	35	19	0	10	11	19	0	3	20
20	0	0	21	20	0	4	57	20	0	14	47
21	0	11	48	21	0	16	24	21	0	9	33
22	0	6	34	22	0	11	10	22	0	4	19
23	0	1	20	23	0	5	56	23	0	15	46
24	0	12	47	24	0	0	42	24	0	10	32
25	0	7	33	25	0	12	9	25	0	5	18
26	0	2	19	26	0	6	55	26	0	0	4
27	0	13	46	27	0	1	41	27	0	11	31
28	0	8	32	28	0	13	8	28	0	6	17
29	0	3	18	29	0	7	54	29	0	1	3
30	0	14	45	30	0	2	40	30	0	12	30
31	0	9	31					31	0	7	16

TABLE 1

FIRST TOC FOR EACH DAY

TIMES OF COINCIDENCE (NULL) EPHEMERIS
TELEVISION LINE 10 ODD SYNC
33,666.666 MICROSECONDS/PERIOD

DATE	TIME			DATE	TIME			DATE	TIME		
1972	H	M	S	1972	H	M	S	1972	H	M	S
JAN 1	0	2	2	FEB 1	0	6	38	MAR 1	0	5	1
2	0	13	29	2	0	1	24	2	0	16	28
3	0	8	15	3	0	12	51	3	0	11	14
4	0	3	1	4	0	7	37	4	0	6	0
5	0	14	28	5	0	2	23	5	0	0	46
6	0	9	14	6	0	13	50	6	0	12	13
7	0	4	0	7	0	8	36	7	0	6	59
8	0	15	27	8	0	3	22	8	0	1	45
9	0	10	13	9	0	14	49	9	0	13	12
10	0	4	59	10	0	9	35	10	0	7	58
11	0	16	26	11	0	4	21	11	0	2	44
12	0	11	12	12	0	15	48	12	0	14	11
13	0	5	58	13	0	10	34	13	0	8	57
14	0	0	44	14	0	5	20	14	0	3	43
15	0	12	11	15	0	0	6	15	0	15	10
16	0	6	57	16	0	11	33	16	0	9	56
17	0	1	43	17	0	6	19	17	0	4	42
18	0	13	10	18	0	1	5	18	0	16	9
19	0	7	56	19	0	12	32	19	0	10	55
20	0	2	42	20	0	7	18	20	0	5	41
21	0	14	9	21	0	2	4	21	0	0	27
22	0	8	55	22	0	13	31	22	0	11	54
23	0	3	41	23	0	8	17	23	0	6	40
24	0	15	8	24	0	3	3	24	0	1	26
25	0	9	54	25	0	14	30	25	0	12	53
26	0	4	40	26	0	9	16	26	0	7	39
27	0	16	7	27	0	4	2	27	0	2	25
28	0	10	53	28	0	15	29	28	0	13	52
29	0	5	39	29	0	10	15	29	0	8	38
30	0	0	25					30	0	3	24
31	0	11	52					31	0	14	51

UNCLASSIFIED

TABLE 1

FIRST TOC FOR EACH DAY

TIMES OF COINCIDENCE (NULL) EPHEMERIS
TELEVISION LINE 10 ODD SYNC
33,666.666 MICROSECONDS/PERIOD

DATE 1972	TIME H	M	S	DATE 1972	TIME H	M	S	DATE 1972	TIME H	M	S
APR 1	0	9	37	MAY 1	0	2	46	JUN 1	0	7	22
2	0	4	23	2	0	14	13	2	0	2	8
3	0	15	50	3	0	8	59	3	0	13	35
4	0	10	36	4	0	3	45	4	0	8	21
5	0	5	22	5	0	15	12	5	0	3	7
6	0	0	8	6	0	9	58	6	0	14	34
7	0	11	35	7	0	4	44	7	0	9	20
8	0	6	21	8	0	16	11	8	0	4	6
9	0	1	7	9	0	10	57	9	0	15	33
10	0	12	34	10	0	5	43	10	0	10	19
11	0	7	20	11	0	0	29	11	0	5	5
12	0	2	6	12	0	11	56	12	0	16	32
13	0	13	33	13	0	6	42	13	0	11	18
14	0	8	19	14	0	1	28	14	0	6	4
15	0	3	5	15	0	12	55	15	0	0	50
16	0	14	32	16	0	7	41	16	0	12	17
17	0	9	18	17	0	2	27	17	0	7	3
18	0	4	4	18	0	13	54	18	0	1	49
19	0	15	31	19	0	8	40	19	0	13	16
20	0	10	17	20	0	3	26	20	0	8	2
21	0	5	3	21	0	14	53	21	0	2	48
22	0	16	30	22	0	9	39	22	0	14	15
23	0	11	16	23	0	4	25	23	0	9	1
24	0	6	2	24	0	15	52	24	0	3	47
25	0	0	48	25	0	10	38	25	0	15	14
26	0	12	15	26	0	5	24	26	0	10	0
27	0	7	1	27	0	0	10	27	0	4	46
28	0	1	47	28	0	11	37	28	0	16	13
29	0	13	14	29	0	6	23	29	0	10	59
30	0	8	0	30	0	1	9	30	0	5	45
				31	0	12	36				

TABLE 2

ALL TOC'S IN A DAY

TIMES OF COINCIDENCE (NULL) EPHEMERIS

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

H	M	S	H	M	S	H	M	S
0	0	0	11	7	20	22	14	40
0	16	41	11	24	1	22	31	21
0	33	22	11	40	42	22	48	2
0	50	3	11	57	23	23	4	43
1	6	44	12	14	4	23	21	24
1	23	25	12	30	45	23	38	5
1	40	6	12	47	26	23	54	46
1	56	47	13	4	7			
2	13	28	13	20	48			
2	30	9	13	37	29			
2	46	50	13	54	10			
3	3	31	14	10	51			
3	20	12	14	27	32			
3	36	53	14	44	13			
3	53	34	15	0	54			
4	10	15	15	17	35			
4	26	56	15	34	16			
4	43	37	15	50	57			
5	0	18	16	7	38			
5	16	59	16	24	19			
5	33	40	16	41	0			
5	50	21	16	57	41			
6	7	2	17	14	22			
6	23	43	17	31	3			
6	40	24	17	47	44			
6	57	5	18	4	25			
7	13	46	18	21	6			
7	30	27	18	37	47			
7	47	8	18	54	28			
8	3	49	19	11	9			
8	20	30	19	27	50			
8	37	11	19	44	31			
8	53	52	20	1	12			
9	10	33	20	17	53			
9	27	14	20	34	34			
9	43	55	20	51	15			
10	0	36	21	7	56			
10	17	17	21	24	37			
10	33	58	21	41	18			
10	50	39	21	57	59			

TABLE 3

INTERPOLATIONS FOR ALL SECONDS BETWEEN TOC'S

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

M	S	(μS)	M	S	(μS)	M	S	(μS)	M	S	(μS)
0	1	1000.000	0	51	17633.333	1	41	900.000	2	31	17533.333
0	2	2000.000	0	52	18633.333	1	42	1900.000	2	32	18533.333
0	3	3000.000	0	53	19633.333	1	43	2900.000	2	33	19533.333
0	4	4000.000	0	54	20633.333	1	44	3900.000	2	34	20533.333
0	5	5000.000	0	55	21633.333	1	45	4900.000	2	35	21533.333
0	6	6000.000	0	56	22633.333	1	46	5900.000	2	36	22533.333
0	7	7000.000	0	57	23633.333	1	47	6900.000	2	37	23533.333
0	8	8000.000	0	58	24633.333	1	48	7900.000	2	38	24533.333
0	9	9000.000	0	59	25633.333	1	49	8900.000	2	39	25533.333
0	10	10000.000	1	0	26633.333	1	50	9900.000	2	40	26533.333
0	11	11000.000	1	1	27633.333	1	51	10900.000	2	41	27533.333
0	12	12000.000	1	2	28633.333	1	52	11900.000	2	42	28533.333
0	13	13000.000	1	3	29633.333	1	53	12900.000	2	43	29533.333
0	14	14000.000	1	4	30633.333	1	54	13900.000	2	44	30533.333
0	15	15000.000	1	5	31633.333	1	55	14900.000	2	45	31533.333
0	16	16000.000	1	6	32633.333	1	56	15900.000	2	46	32533.333
0	17	17000.000	1	7	266.667	1	57	16900.000	2	47	166.667
0	18	18000.000	1	8	1266.667	1	58	17900.000	2	48	1166.667
0	19	19000.000	1	9	2266.667	1	59	18900.000	2	49	2166.667
0	20	20000.000	1	10	3266.667	2	0	19900.000	2	50	3166.667
0	21	21000.000	1	11	4266.667	2	1	20900.000	2	51	4166.667
0	22	22000.000	1	12	5266.667	2	2	21900.000	2	52	5166.667
0	23	23000.000	1	13	6266.667	2	3	22900.000	2	53	6166.667
0	24	24000.000	1	14	7266.667	2	4	23900.000	2	54	7166.667
0	25	25000.000	1	15	8266.667	2	5	24900.000	2	55	8166.667
0	26	26000.000	1	16	9266.667	2	6	25900.000	2	56	9166.667
0	27	27000.000	1	17	10266.667	2	7	26900.000	2	57	10166.667
0	28	28000.000	1	18	11266.667	2	8	27900.000	2	58	11166.667
0	29	29000.000	1	19	12266.667	2	9	28900.000	2	59	12166.667
0	30	30000.000	1	20	13266.667	2	10	29900.000	3	0	13166.667
0	31	31000.000	1	21	14266.667	2	11	30900.000	3	1	14166.667
0	32	32000.000	1	22	15266.667	2	12	31900.000	3	2	15166.667
0	33	33000.000	1	23	16266.667	2	13	32900.000	3	3	16166.667
0	34	633.333	1	24	17266.667	2	14	533.333	3	4	17166.667
0	35	1633.333	1	25	18266.667	2	15	1533.333	3	5	18166.667
0	36	2633.333	1	26	19266.667	2	16	2533.333	3	6	19166.667
0	37	3633.333	1	27	20266.667	2	17	3533.333	3	7	20166.667
0	38	4633.333	1	28	21266.667	2	18	4533.333	3	8	21166.667
0	39	5633.333	1	29	22266.667	2	19	5533.333	3	9	22166.667
0	40	6633.333	1	30	23266.667	2	20	6533.333	3	10	23166.667
0	41	7633.333	1	31	24266.667	2	21	7533.333	3	11	24166.667
0	42	8633.333	1	32	25266.667	2	22	8533.333	3	12	25166.667
0	43	9633.333	1	33	26266.667	2	23	9533.333	3	13	26166.667
0	44	10633.333	1	34	27266.667	2	24	10533.333	3	14	27166.667
0	45	11633.333	1	35	28266.667	2	25	11533.333	3	15	28166.667
0	46	12633.333	1	36	29266.667	2	26	12533.333	3	16	29166.667
0	47	13633.333	1	37	30266.667	2	27	13533.333	3	17	30166.667
0	48	14633.333	1	38	31266.667	2	28	14533.333	3	18	31166.667
0	49	15633.333	1	39	32266.667	2	29	15533.333	3	19	32166.667
0	50	16633.333	1	40	33266.667	2	30	16533.333	3	20	33166.667

TABLE 3

INTERPOLATIONS FOR ALL SECONDS BETWEEN TOC'S

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

M	S	(μS)	M	S	(μS)	M	S	(μS)	M	S	(μS)
3	21	800.000	4	11	17433.333	5	1	700.000	5	51	17333.333
3	22	1800.000	4	12	18433.333	5	2	1700.000	5	52	18333.333
3	23	2800.000	4	13	19433.333	5	3	2700.000	5	53	19333.333
3	24	3800.000	4	14	20433.333	5	4	3700.000	5	54	20333.333
3	25	4800.000	4	15	21433.333	5	5	4700.000	5	55	21333.333
3	26	5800.000	4	16	22433.333	5	6	5700.000	5	56	22333.333
3	27	6800.000	4	17	23433.333	5	7	6700.000	5	57	23333.333
3	28	7800.000	4	18	24433.333	5	8	7700.000	5	58	24333.333
3	29	8800.000	4	19	25433.333	5	9	8700.000	5	59	25333.333
3	30	9800.000	4	20	26433.333	5	10	9700.000	6	0	26333.333
3	31	10800.000	4	21	27433.333	5	11	10700.000	6	1	27333.333
3	32	11800.000	4	22	28433.333	5	12	11700.000	6	2	28333.333
3	33	12800.000	4	23	29433.333	5	13	12700.000	6	3	29333.333
3	34	13800.000	4	24	30433.333	5	14	13700.000	6	4	30333.333
3	35	14800.000	4	25	31433.333	5	15	14700.000	6	5	31333.333
3	36	15800.000	4	26	32433.333	5	16	15700.000	6	6	32333.333
3	37	16800.000	4	27	66.667	5	17	16700.000	6	7	33333.333
3	38	17800.000	4	28	1066.667	5	18	17700.000	6	8	966.667
3	39	18800.000	4	29	2066.667	5	19	18700.000	6	9	1966.667
3	40	19800.000	4	30	3066.667	5	20	19700.000	6	10	2966.667
3	41	20800.000	4	31	4066.667	5	21	20700.000	6	11	3966.667
3	42	21800.000	4	32	5066.667	5	22	21700.000	6	12	4966.667
3	43	22800.000	4	33	6066.667	5	23	22700.000	6	13	5966.667
3	44	23800.000	4	34	7066.667	5	24	23700.000	6	14	6966.667
3	45	24800.000	4	35	8066.667	5	25	24700.000	6	15	7966.667
3	46	25800.000	4	36	9066.667	5	26	25700.000	6	16	8966.667
3	47	26800.000	4	37	10066.667	5	27	26700.000	6	17	9966.667
3	48	27800.000	4	38	11066.667	5	28	27700.000	6	18	10966.667
3	49	28800.000	4	39	12066.667	5	29	28700.000	6	19	11966.667
3	50	29800.000	4	40	13066.667	5	30	29700.000	6	20	12966.667
3	51	30800.000	4	41	14066.667	5	31	30700.000	6	21	13966.667
3	52	31800.000	4	42	15066.667	5	32	31700.000	6	22	14966.667
3	53	32800.000	4	43	16066.667	5	33	32700.000	6	23	15966.667
3	54	433.333	4	44	17066.667	5	34	333.333	6	24	16966.667
3	55	1433.333	4	45	18066.667	5	35	1333.333	6	25	17966.667
3	56	2433.333	4	46	19066.667	5	36	2333.333	6	26	18966.667
3	57	3433.333	4	47	20066.667	5	37	3333.333	6	27	19966.667
3	58	4433.333	4	48	21066.667	5	38	4333.333	6	28	20966.667
3	59	5433.333	4	49	22066.667	5	39	5333.333	6	29	21966.667
4	0	6433.333	4	50	23066.667	5	40	6333.333	6	30	22966.667
4	1	7433.333	4	51	24066.667	5	41	7333.333	6	31	23966.667
4	2	8433.333	4	52	25066.667	5	42	8333.333	6	32	24966.667
4	3	9433.333	4	53	26066.667	5	43	9333.333	6	33	25966.667
4	4	10433.333	4	54	27066.667	5	44	10333.333	6	34	26966.667
4	5	11433.333	4	55	28066.667	5	45	11333.333	6	35	27966.667
4	6	12433.333	4	56	29066.667	5	46	12333.333	6	36	28966.667
4	7	13433.333	4	57	30066.667	5	47	13333.333	6	37	29966.667
4	8	14433.333	4	58	31066.667	5	48	14333.333	6	38	30966.667
4	9	15433.333	4	59	32066.667	5	49	15333.333	6	39	31966.667
4	10	16433.333	5	0	33066.667	5	50	16333.333	6	40	32966.667

TABLE 3

INTERPOLATIONS FOR ALL SECONDS BETWEEN TOC'S

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

M	S	(µS)	M	S	(µS)	M	S	(µS)	M	S	(µS)
6	41	600.000	7	31	17233.333	8	21	500.000	9	11	17133.333
6	42	1600.000	7	32	18233.333	8	22	1500.000	9	12	18133.333
6	43	2600.000	7	33	19233.333	8	23	2500.000	9	13	19133.333
6	44	3600.000	7	34	20233.333	8	24	3500.000	9	14	20133.333
6	45	4600.000	7	35	21233.333	8	25	4500.000	9	15	21133.333
6	46	5600.000	7	36	22233.333	8	26	5500.000	9	16	22133.333
6	47	6600.000	7	37	23233.333	8	27	6500.000	9	17	23133.333
6	48	7600.000	7	38	24233.333	8	28	7500.000	9	18	24133.333
6	49	8600.000	7	39	25233.333	8	29	8500.000	9	19	25133.333
6	50	9600.000	7	40	26233.333	8	30	9500.000	9	20	26133.333
6	51	10600.000	7	41	27233.333	8	31	10500.000	9	21	27133.333
6	52	11600.000	7	42	28233.333	8	32	11500.000	9	22	28133.333
6	53	12600.000	7	43	29233.333	8	33	12500.000	9	23	29133.333
6	54	13600.000	7	44	30233.333	8	34	13500.000	9	24	30133.333
6	55	14600.000	7	45	31233.333	8	35	14500.000	9	25	31133.333
6	56	15600.000	7	46	32233.333	8	36	15500.000	9	26	32133.333
6	57	16600.000	7	47	33233.333	8	37	16500.000	9	27	33133.333
6	58	17600.000	7	48	866.667	8	38	17500.000	9	28	766.667
6	59	18600.000	7	49	1866.667	8	39	18500.000	9	29	1766.667
7	0	19600.000	7	50	2866.667	8	40	19500.000	9	30	2766.667
7	1	20600.000	7	51	3866.667	8	41	20500.000	9	31	3766.667
7	2	21600.000	7	52	4866.667	8	42	21500.000	9	32	4766.667
7	3	22600.000	7	53	5866.667	8	43	22500.000	9	33	5766.667
7	4	23600.000	7	54	6866.667	8	44	23500.000	9	34	6766.667
7	5	24600.000	7	55	7866.667	8	45	24500.000	9	35	7766.667
7	6	25600.000	7	56	8866.667	8	46	25500.000	9	36	8766.667
7	7	26600.000	7	57	9866.667	8	47	26500.000	9	37	9766.667
7	8	27600.000	7	58	10866.667	8	48	27500.000	9	38	10766.667
7	9	28600.000	7	59	11866.667	8	49	28500.000	9	39	11766.667
7	10	29600.000	8	0	12866.667	8	50	29500.000	9	40	12766.667
7	11	30600.000	8	1	13866.667	8	51	30500.000	9	41	13766.667
7	12	31600.000	8	2	14866.667	8	52	31500.000	9	42	14766.667
7	13	32600.000	8	3	15866.667	8	53	32500.000	9	43	15766.667
7	14	233.333	8	4	16866.667	8	54	133.333	9	44	16766.667
7	15	1233.333	8	5	17866.667	8	55	1133.333	9	45	17766.667
7	16	2233.333	8	6	18866.667	8	56	2133.333	9	46	18766.667
7	17	3233.333	8	7	19866.667	8	57	3133.333	9	47	19766.667
7	18	4233.333	8	8	20866.667	8	58	4133.333	9	48	20766.667
7	19	5233.333	8	9	21866.667	8	59	5133.333	9	49	21766.667
7	20	6233.333	8	10	22866.667	9	0	6133.333	9	50	22766.667
7	21	7233.333	8	11	23866.667	9	1	7133.333	9	51	23766.667
7	22	8233.333	8	12	24866.667	9	2	8133.333	9	52	24766.667
7	23	9233.333	8	13	25866.667	9	3	9133.333	9	53	25766.667
7	24	10233.333	8	14	26866.667	9	4	10133.333	9	54	26766.667
7	25	11233.333	8	15	27866.667	9	5	11133.333	9	55	27766.667
7	26	12233.333	8	16	28866.667	9	6	12133.333	9	56	28766.667
7	27	13233.333	8	17	29866.667	9	7	13133.333	9	57	29766.667
7	28	14233.333	8	18	30866.667	9	8	14133.333	9	58	30766.667
7	29	15233.333	8	19	31866.667	9	9	15133.333	9	59	31766.667
7	30	16233.333	8	20	32866.667	9	10	16133.333	10	0	32766.667

TABLE 3

INTERPOLATIONS FOR ALL SECONDS BETWEEN TOC'S

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

M	S	(µS)	M	S	(µS)	M	S	(µS)	M	S	(µS)
10	1	400.000	10	51	17033.333	11	41	300.000	12	31	16933.333
10	2	1400.000	10	52	18033.333	11	42	1300.000	12	32	17933.333
10	3	2400.000	10	53	19033.333	11	43	2300.000	12	33	18933.333
10	4	3400.000	10	54	20033.333	11	44	3300.000	12	34	19933.333
10	5	4400.000	10	55	21033.333	11	45	4300.000	12	35	20933.333
10	6	5400.000	10	56	22033.333	11	46	5300.000	12	36	21933.333
10	7	6400.000	10	57	23033.333	11	47	6300.000	12	37	22933.333
10	8	7400.000	10	58	24033.333	11	48	7300.000	12	38	23933.333
10	9	8400.000	10	59	25033.333	11	49	8300.000	12	39	24933.333
10	10	9400.000	11	0	26033.333	11	50	9300.000	12	40	25933.333
10	11	10400.000	11	1	27033.333	11	51	10300.000	12	41	26933.333
10	12	11400.000	11	2	28033.333	11	52	11300.000	12	42	27933.333
10	13	12400.000	11	3	29033.333	11	53	12300.000	12	43	28933.333
10	14	13400.000	11	4	30033.333	11	54	13300.000	12	44	29933.333
10	15	14400.000	11	5	31033.333	11	55	14300.000	12	45	30933.333
10	16	15400.000	11	6	32033.333	11	56	15300.000	12	46	31933.333
10	17	16400.000	11	7	33033.333	11	57	16300.000	12	47	32933.333
10	18	17400.000	11	8	666.667	11	58	17300.000	12	48	566.667
10	19	18400.000	11	9	1666.667	11	59	18300.000	12	49	1566.667
10	20	19400.000	11	10	2666.667	12	0	19300.000	12	50	2566.667
10	21	20400.000	11	11	3666.667	12	1	20300.000	12	51	3566.667
10	22	21400.000	11	12	4666.667	12	2	21300.000	12	52	4566.667
10	23	22400.000	11	13	5666.667	12	3	22300.000	12	53	5566.667
10	24	23400.000	11	14	6666.667	12	4	23300.000	12	54	6566.667
10	25	24400.000	11	15	7666.667	12	5	24300.000	12	55	7566.667
10	26	25400.000	11	16	8666.667	12	6	25300.000	12	56	8566.667
10	27	26400.000	11	17	9666.667	12	7	26300.000	12	57	9566.667
10	28	27400.000	11	18	10666.667	12	8	27300.000	12	58	10566.667
10	29	28400.000	11	19	11666.667	12	9	28300.000	12	59	11566.667
10	30	29400.000	11	20	12666.667	12	10	29300.000	13	0	12566.667
10	31	30400.000	11	21	13666.667	12	11	30300.000	13	1	13566.667
10	32	31400.000	11	22	14666.667	12	12	31300.000	13	2	14566.667
10	33	32400.000	11	23	15666.667	12	13	32300.000	13	3	15566.667
10	34	33.333	11	24	16666.667	12	14	33300.000	13	4	16566.667
10	35	1033.333	11	25	17666.667	12	15	933.333	13	5	17566.667
10	36	2033.333	11	26	18666.667	12	16	1933.333	13	6	18566.667
10	37	3033.333	11	27	19666.667	12	17	2933.333	13	7	19566.667
10	38	4033.333	11	28	20666.667	12	18	3933.333	13	8	20566.667
10	39	5033.333	11	29	21666.667	12	19	4933.333	13	9	21566.667
10	40	6033.333	11	30	22666.667	12	20	5933.333	13	10	22566.667
10	41	7033.333	11	31	23666.667	12	21	6933.333	13	11	23566.667
10	42	8033.333	11	32	24666.667	12	22	7933.333	13	12	24566.667
10	43	9033.333	11	33	25666.667	12	23	8933.333	13	13	25566.667
10	44	10033.333	11	34	26666.667	12	24	9933.333	13	14	26566.667
10	45	11033.333	11	35	27666.667	12	25	10933.333	13	15	27566.667
10	46	12033.333	11	36	28666.667	12	26	11933.333	13	16	28566.667
10	47	13033.333	11	37	29666.667	12	27	12933.333	13	17	29566.667
10	48	14033.333	11	38	30666.667	12	28	13933.333	13	18	30566.667
10	49	15033.333	11	39	31666.667	12	29	14933.333	13	19	31566.667
10	50	16033.333	11	40	32666.667	12	30	15933.333	13	20	32566.667

UNCLASSIFIED

TABLE 3

INTERPOLATIONS FOR ALL SECONDS BETWEEN TOC'S

TELEVISION LINE 10 ODD SYNC
33,366.666 MICROSECONDS/PERIOD

M	S	(μS)	M	S	(μS)	M	S	(μS)	M	S	(μS)
13	21	200.000	14	11	16833.333	15	1	100.000	15	51	16733.333
13	22	1200.000	14	12	17833.333	15	2	1100.000	15	52	17733.333
13	23	2200.000	14	13	18833.333	15	3	2100.000	15	53	18733.333
13	24	3200.000	14	14	19833.333	15	4	3100.000	15	54	19733.333
13	25	4200.000	14	15	20833.333	15	5	4100.000	15	55	20733.333
13	26	5200.000	14	16	21833.333	15	6	5100.000	15	56	21733.333
13	27	6200.000	14	17	22833.333	15	7	6100.000	15	57	22733.333
13	28	7200.000	14	18	23833.333	15	8	7100.000	15	58	23733.333
13	29	8200.000	14	19	24833.333	15	9	8100.000	15	59	24733.333
13	30	9200.000	14	20	25833.333	15	10	9100.000	16	0	25733.333
13	31	10200.000	14	21	26833.333	15	11	10100.000	16	1	26733.333
13	32	11200.000	14	22	27833.333	15	12	11100.000	16	2	27733.333
13	33	12200.000	14	23	28833.333	15	13	12100.000	16	3	28733.333
13	34	13200.000	14	24	29833.333	15	14	13100.000	16	4	29733.333
13	35	14200.000	14	25	30833.333	15	15	14100.000	16	5	30733.333
13	36	15200.000	14	26	31833.333	15	16	15100.000	16	6	31733.333
13	37	16200.000	14	27	32833.333	15	17	16100.000	16	7	32733.333
13	38	17200.000	14	28	466.667	15	18	17100.000	16	8	366.667
13	39	18200.000	14	29	1466.667	15	19	18100.000	16	9	1366.667
13	40	19200.000	14	30	2466.667	15	20	19100.000	16	10	2366.667
13	41	20200.000	14	31	3466.667	15	21	20100.000	16	11	3366.667
13	42	21200.000	14	32	4466.667	15	22	21100.000	16	12	4366.667
13	43	22200.000	14	33	5466.667	15	23	22100.000	16	13	5366.667
13	44	23200.000	14	34	6466.667	15	24	23100.000	16	14	6366.667
13	45	24200.000	14	35	7466.667	15	25	24100.000	16	15	7366.667
13	46	25200.000	14	36	8466.667	15	26	25100.000	16	16	8366.667
13	47	26200.000	14	37	9466.667	15	27	26100.000	16	17	9366.667
13	48	27200.000	14	38	10466.667	15	28	27100.000	16	18	10366.667
13	49	28200.000	14	39	11466.667	15	29	28100.000	16	19	11366.667
13	50	29200.000	14	40	12466.667	15	30	29100.000	16	20	12366.667
13	51	30200.000	14	41	13466.667	15	31	30100.000	16	21	13366.667
13	52	31200.000	14	42	14466.667	15	32	31100.000	16	22	14366.667
13	53	32200.000	14	43	15466.667	15	33	32100.000	16	23	15366.667
13	54	33200.000	14	44	16466.667	15	34	33100.000	16	24	16366.667
13	55	833.333	14	45	17466.667	15	35	733.333	16	25	17366.667
13	56	1833.333	14	46	18466.667	15	36	1733.333	16	26	18366.667
13	57	2833.333	14	47	19466.667	15	37	2733.333	16	27	19366.667
13	58	3833.333	14	48	20466.667	15	38	3733.333	16	28	20366.667
13	59	4833.333	14	49	21466.667	15	39	4733.333	16	29	21366.667
14	0	5833.333	14	50	22466.667	15	40	5733.333	16	30	22366.667
14	1	6833.333	14	51	23466.667	15	41	6733.333	16	31	23366.667
14	2	7833.333	14	52	24466.667	15	42	7733.333	16	32	24366.667
14	3	8833.333	14	53	25466.667	15	43	8733.333	16	33	25366.667
14	4	9833.333	14	54	26466.667	15	44	9733.333	16	34	26366.667
14	5	10833.333	14	55	27466.667	15	45	10733.333	16	35	27366.667
14	6	11833.333	14	56	28466.667	15	46	11733.333	16	36	28366.667
14	7	12833.333	14	57	29466.667	15	47	12733.333	16	37	29366.667
14	8	13833.333	14	58	30466.667	15	48	13733.333	16	38	30366.667
14	9	14833.333	14	59	31466.667	15	49	14733.333	16	39	31366.667
14	10	15833.333	15	0	32466.667	15	50	15733.333	16	40	32366.667

DISCUSSION

MRS. CARROLL: Are there any questions?

LCDR POTTS: It's not clear to me why, on your last figure, in the proposed USNO system, there is no requirement to know the equipment delays and propagation delays.

MRS. CARROLL: That would be necessary; it is in all the systems.

LCDR POTTS: I didn't see it listed under that proposed system. Thank you.

MRS. CARROLL: Any other questions?

MR. GATTERER: I'd like to make a couple of comments and ask you a question. I think this stabilizing of line 10 and putting line 10 on time is a very valuable contribution. I would like to point out that NBS did stabilize the color subcarrier frequency in our early line 10 systems. Is the pulse discriminator circuit in your present equipment different than in the equipment we originally supplied to you? Is there an improvement, is it cheaper, and that sort of thing?

MRS. CARROLL: The specifications of that piece of equipment have been shown. I think it is different, because, as I mentioned before, this piece of equipment counts lines, and I believe the piece of equipment that you are referring to recognizes the line 10 because of the particular unique pulse that is located on line 10. All this discriminator does is count the lines until it gets to 10, and then it uses that line. In other words, this piece of equipment could be made to count to any number of lines, whereas yours requires a particular uniqueness about a line, in particular line 10.

MODERATOR: Thank you, Mrs. Carroll.