17 June 1952

STERILIZED WORKING LEVEL MEMO

From: Mac
To: Paul and Dave
Subj: Visit to National Bureau of Standards, High-Frequency Standards Division; report on

Encl: (1) USNBS, Standard Frequencies and Time Signals, WWV and WWVH, dtd Apr 15, 1952
(2) USNBS, Standard Frequency Broadcast Reception, preprint 51-28, dtd May 2, 1951

1. Visited NBS, 16 June 1952, and contacted Mr. E. L. Hall (Telephone OR-4040 Ext. 217) in Radio Building No. 214.

2. Enclosures (1) and (2) cover the majority of questions you had in mind.

3. Of particular interest to you is the information on transmission from MSF, Rugby, England, which is covered on page 14 of enclosure (2). The report also includes a survey of world reception from WWV and WWVH.

4. Mr. Hall states England is considering to broadcast on a round-the-clock basis and his superior, Mr. W. D. George, is on an international committee regulating such matters. I will follow up on the development of this problem and will report to you any significant proposals or recommendations.

5. Mr. Hall also stated that Japan is coming into the broadcasting picture. In addition, the reception in the Korean area is very poor owing to interference from military broadcasting when the assigned frequencies are not rigidly maintained.

6. The NBS had on file a proposal from:

Specific Products
5864 Hollywood Blvd.
Hollywood 28, Calif.

on tentative specifications for a specially designed receiver, Model WWVR, to receive just time ticks on 5, 10, and 15 megacyles. The cost is approximately $400.00 and the panel, I would estimate from the drawing, is 5" x 10". This does not meet our requirements of cost and size but may be a source for our custom built specifications. Won't follow up on this unless I hear from you.

Sincerely,

"Mac"

14.8

April 15, 1952

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D. C.

Letter Circular
LC1009

(Supersedes
LC974)

STANDARD FREQUENCIES AND TIME SIGNALS WWV AND WWVH

Radio Station WWV (in operation since 1923) and WWVH (since 1949) now broadcast continuously, night and day, giving six widely used services: STANDARD RADIO FREQUENCIES, STANDARD TIME INTERVALS, TIME ANNOUNCEMENTS, STANDARD MUSICAL PITCH, STANDARD AUDIO FREQUENCIES, **AND** RADIO PROPAGATION NOTICES.

1. Radio Frequencies and Station Locations

Station WWV (N 38° 59' 33", W 76° 50' 52"; near Washington, D. C.) broadcasts continuously, night and day, on standard radio frequencies of 2.5, 5, 10, 15, 20, and 25 Mc.

Station WWVH (N 20° 46' 02", W 156° 27' 42"; Maui, Territory of Hawaii) broadcasts on standard radio frequencies of 5, 10 and 15 Mc. The WWVH broadcast is interrupted for 4 minutes following each hour and half hour and for periods of 34 minutes each day beginning at 1900 UT (Universal Time). Also, during the week including the third Tuesday of each month, the WWVH broadcast is interrupted from 1900 to 2200 UT as follows: 5 Mc on Tuesday; 10 Mc on Wednesday; 15 Mc on Thursday.

2. Time Signals and Standard Time Intervals

The audio frequencies are interrupted for intervals of precisely one minute. They are resumed precisely on the hour and each five minutes thereafter. They are in agreement with the basic time service of the U. S. Naval Observatory so that they mark accurately the hour and the successive 5-minute periods.

Universal Time (Greenwich Civil Time or Greenwich Mean Time) is announced in telegraphic code each five minutes starting with 0000 (midnight). Time announcements are given just prior to and are with reference to return of the audio frequencies.

A voice announcement of Eastern Standard Time is given each five minutes from station WWV; this precedes and follows each telegraphic code announcement.

A pulse on each carrier frequency of 0.005-second duration occurs at intervals of precisely one second. The pulse consists of five cycles, each of 0.001-second duration.

Encl

NATIONAL BUREAU OF STANDARDS

STANDARD FREQUENCIES AND TIME SIGNALS, WWV AND WWVH

WWV
BROADCAST CONTINUOUSLY

MC	POWER, KW	MODULATIONS, C/S
2.5	0.7	1,440 OR 600
5	8.0	1,440 OR 600
10	9.0	1,440 OR 600
15	9.0	1,440 OR 600
20	8.5 [a]	1,440 OR 600
25	0.1	1,440 OR 600
30 [b]	0.1	1
35 [b]	0.1	1

WWVH
BROADCAST CONTINUOUSLY [c]

MC	POWER, KW	MODULATIONS, C/S
5	2.0	1;440 OR 600
10	2.0	1;440 OR 600
15	2.0	1;440 OR 600

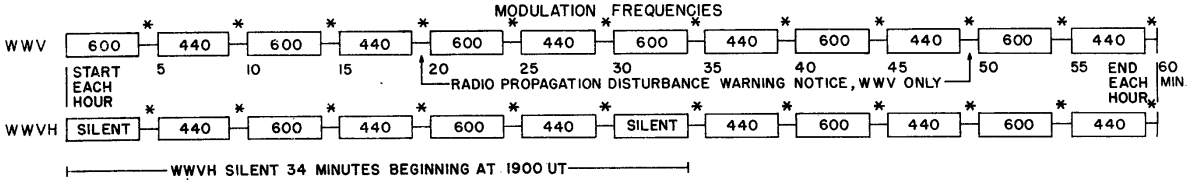
(a) 2.0 KW, FOR FIRST 4 WORK DAYS AFTER FIRST SUNDAY OF EVEN MONTHS.

(b) TO BE DISCONTINUED JANUARY 1, 1953.

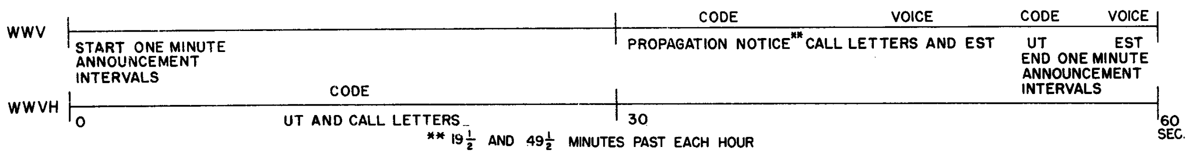
(c) REGULAR INTERRUTIONS EXPLAINED ON PAGE 1

NOTE: AMPLITUDE MODULATION, WWV AND WWVH PULSE, 100%, TONE, 75%.

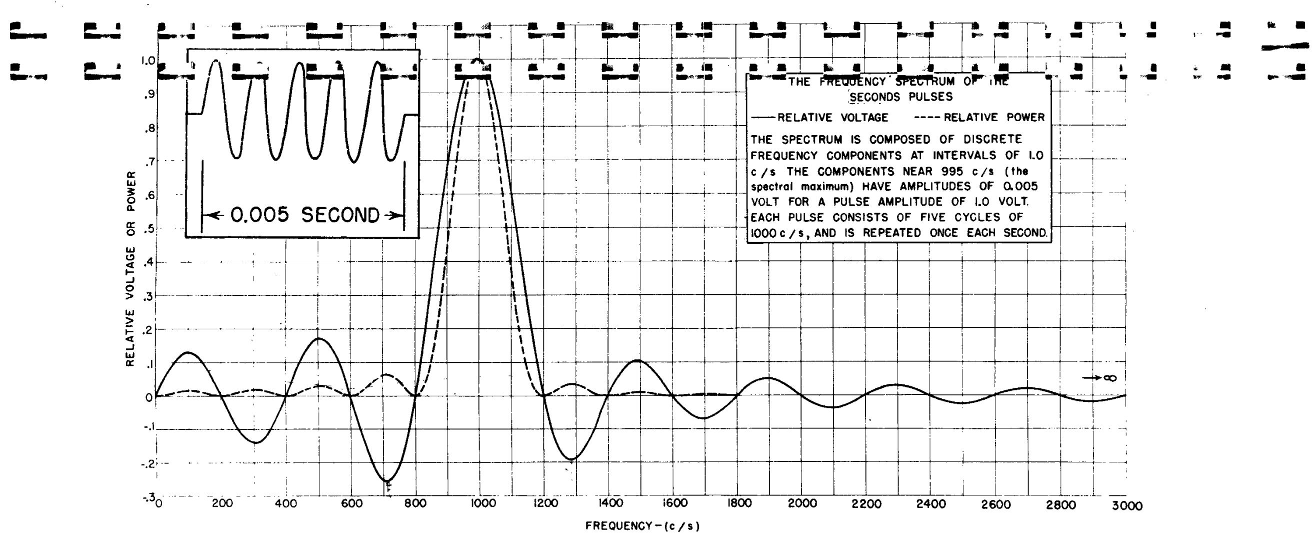
MODULATION FREQUENCIES



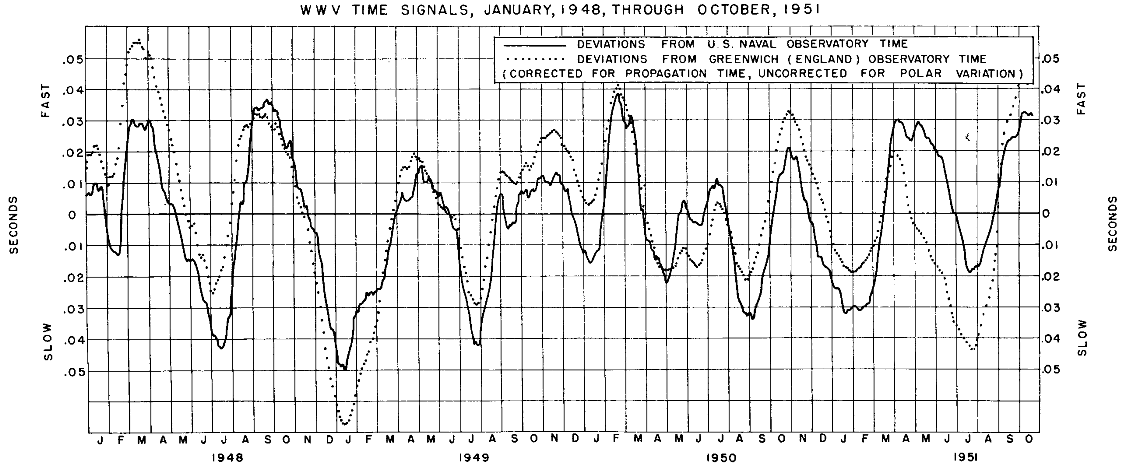
*ANNOUNCEMENT INTERVALS



** 19½ AND 49½ MINUTES PAST EACH HOUR



WWV TIME SIGNALS, JANUARY, 1948, THROUGH OCTOBER, 1951



3. Audio Frequencies and Musical Pitch

Two standard audio frequencies, 440 and 600 cycles per second, are broadcast on all radio carrier frequencies. The audio frequencies are given alternately, starting with 600 cycles on the hour for four minutes, interrupted one minute, followed by 440 cycles for four minutes, and interrupted one minute. Each ten-minute period is the same. The 440-cycle tone is the standard musical pitch A above middle C.

4. Accuracy

Frequencies transmitted from WWV and WWVH are accurate to within 2 parts in 10^8; this is with reference to the mean solar second, 100-day interval, as determined by the U. S. Naval Observatory with a precision of better than 3 parts in 10^9. Time intervals, as transmitted, are accurate within $\pm\ |2$ parts in $10^8 + 1$ microsecond$|$.

Frequencies received may be as accurate as those transmitted for several hours per day during total light or total darkness over the transmission path at locations in the service range. During the course of the day errors in the received frequencies may vary approximately between -3 to +3 parts in 10^7. During ionospheric storms transient conditions in the propagating medium may cause momentary changes as large as 1 part in 10^6.

Time intervals, as received, are normally accurate within $\pm\ |2$ parts in $10^8 + 1$ millisecond$|$. Transient conditions in the ionosphere at times cause received pulses to scatter by several milliseconds.

Corrections for the slight errors in absolute time and frequency as broadcast are available quarterly to organizations having need for corrections.

5. Radio Propagation Disturbance Warning Notice from WWV

An announcement of North Atlantic radio propagation conditions is broadcast in code on each of the standard radio frequencies at 19 1/2 and 49 1/2 minutes past the hour. If a warning of disturbance is in effect, the letter "W" (in International Morse Code) is repeated 10 times (keying tone 800 c/s) prior to the time announcement; if unstable conditions are expected, the letter "U" is repeated 10 times (keying tone 1200 c/s); if there is no warning, the letter "N" is repeated 10 times (keying tone 600 c/s). These announcements are pertinent only to transmission paths in the North Atlantic area.

CRPL PREPRINT 51-28

ISSUED MAY 2, 1951

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
CENTRAL RADIO PROPAGATION LABORATORY
WASHINGTON, D.C.

STANDARD FREQUENCY BROADCAST RECEPTION

By

E. L. Hall

Encl. (2)

STANDARD FREQUENCY BROADCAST RECEPTION

By E. L. Hall
National Bureau of Standards
Washington 25, D. C.

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ABSTRACT

This paper gives the results of a compilation of many thousands of observations during 1950 on reception of standard frequency transmissions from the National Bureau of Standards experimental station WWVH, Maui, T.H., and the more powerful station WWV, Beltsville, Maryland. Observations were made by several government agencies and by individuals at numerous points in the United States, Alaska, the Pacific area, Australia, and Jamaica. The data presented in tabular and chart form extend much of the information presented in a previous report to other seasons of the year.

A limited amount of information is given on the 5-Mc broadcasts from JJY, Tokyo, and 5- and 10-Mc broadcasts from MSF, Rugby, England.

The reports submitted indicate an increase in the standard frequency coverage by operation of station WWVH, and no marked difficulty from the operation of WWVH and WWV on the same frequencies. Data on the operation of JJY and MSF have been too meager to draw any definite conclusions other than that no undesired effects were produced in the United States.

CONTENTS

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I. Introduction

The present paper presents some of the results of reception of standard frequency broadcasts, as reported to the National Bureau of Standards, with a brief record of the establishment of such services, and certain conclusions concerning world-wide coverage of standard frequency and time services.

1. In 1923 the Bureau of Standards began transmissions of standard frequencies from WWV.[1/] These transmissions consisted of several groups of frequencies, each of which was available for a few minutes in the evening once a month. The transmissions were announced in advance in the press, in radio periodicals, and in the Radio Service Bulletin, a former publication of the Department of Commerce. Later the service was gradually expanded until it has become available continuously 24 hours per day on eight frequencies.[2/] Many government agencies and other organizations and individuals have cooperated with the Bureau in making these services of maximum utility by sending reception reports from which the coverage of the various frequencies was determined. These reports indicated that adequate coverage was not obtained some of the time in certain areas during some seasons. The ideal of standard frequencies available all of the time at all places was not realized.[3/]

2. This led to the establishment of a second standard frequency station on an experimental basis on the island of Maui, T.H., in November 1948. This station, WWVH, operates on three of the frequencies of WWV, i.e., 5, 10, and 15 Mc, with a power of 400 watts. Station WWVH is maintained on the correct frequencies with reference to WWV by means of special piezo oscillators of high stability and special monitoring techniques.[4/]

One of the questions to be answered was whether interference would be experienced by users of these stations because of simultaneous operation. Another question related to how much the standard frequency coverage was extended by the second station.

The answers to these questions were again provided by a corps of observers in various Government agencies and by individual observers.

1/ Standard frequency dissemination, M. S. Strock, Proc.IRE 15, 727 (1927).
2/ Letter Circular LC974, Jan. 12, 1950, CRPL, National Bureau of Standards.
3/ Radio dissemination of the national standard of frequency, J.H.Dellinger and E.L.Hall, Radio Engineering, 12, No. 5, 23 (1932).
4/ Frequency and time determinations at standard frequency broadcast station WWVH, V. E. Heaton, Tele-Tech 10, 36, March 1951.

3. Station JJY, Tokyo, Japan, gives standard frequency broadcasts on 4 and 8 Mc. Late in 1949 experimental standard frequency broadcasts were given on 5 Mc for three weeks and were intended to give practical data on 5-Mc reception in Japan and other far eastern areas not covered well by WWV or WWVH.

Reception of WWV is not always satisfactory in England and Europe. The National Physical Laboratory on February 1, 1950, began an experimental standard frequency transmission for a half-hour each day on each of the frequencies 5 and 10 Mc from Rugby, England.[5/] [6/] The station call letters are MSF. Reports of reception of this station were received from a number of localities in this country and a few other points.

II. Data on Reception of WWV and WWVH

1. CAA Data

The Civil Aeronautics Administration submitted over 13,000 observations on reception of stations WWVH and WWV from September, 1949, through July, 1950. The reports came from three main regions which may be defined as the west coast, Alaska, and islands of the Pacific Ocean. These are regions most likely to be benefited by transmissions from station WWVH. The west coast included areas in California and Washington. Points in Alaska included Anchorage, Annette Island, Fairbanks, and Nome. The Pacific islands were Canton, Guam, Midway and Wake. The results are summarized in Table I, where "Better," "Worse," and "Same" refer to the reception of standard frequency and time signals as changed by the addition of station WWVH. "Better" means either a stronger signal, or extension of the number of hours per day that standard frequencies are available. "Same" indicates no marked change in signal intensities or increase in the hours of availability of the signals beyond that noted for WWV. To be truly "Same" the tests should have been made throughout the twenty-four hours. Very little of the data met this requirement, but was interpreted on the basis of conditions at the times of observation.

The intended meaning of "Worse" was that standard frequency reception was actually worse at the location because of WWVH interfering with WWV and making accurate frequency or time measurements more difficult. One and one-half percent of observations were marked "Worse", but it is believed that many of these were erroneous. Correspondence indicated that some of such markings were intended to indicate that WWV was of greater intensity. Some of these data sheets were forwarded to the observers, were corrected and returned.

The data in Table I indicate 20% better reception for the west coast, 67% better for the Alaskan area, and about 88% better for the Pacific area.

5/ U.K. Standard Frequencies, Wireless World 56, 99, March 1950.
6/ Standard Frequency Transmissions, A. Graham Thomson, Wireless World, 56, 137, April 1950.

2. FCC Data

Observers in the field offices of the Federal Communications Commission were well trained and equipped for accurate measurements. They submitted several thousand observations on the WWV-WWVH transmissions. These reports were divided into two groups for the United States, those east of the Rocky Mountains comprising ten localities, and those west of the Rocky Mountains, of which there were seven localities. Six of the latter were along the seaboard. Observations were also made at Fort Hase, Oahu, T.H.

The results are summarized in Table II where "Better", "Worse," and "Same" have the same meanings as given above for data from CAA. Reception east of the Rocky Mountains would not be expected to be improved by a 400-watt station in Hawaii, hence 97% "Same" seems reasonable. The region west of the Rocky Mountains showed a 30% improvement. It is rather surprising to find only about 55% improvement at Fort Hase so near to WWVH. The reason appears to be that WWV's 15-Mc transmission is of equal or greater intensity than WWVH's and hence given a large number for "Same."

3. Adak, Alaska, Data

Monthly reports of reception of WWVH and WWV were received from the U.S. Army's Ionospheric Station at Adak, Alaska, beginning in November, 1949. These reports usually gave signal intensity readings for each hour of each day of the month for 5, 10 and 15 Mc from WWVH and 20 Mc from WWV. The signal intensity was given on a 0-9 basis each hour, from which the average intensity for the month was computed. A low monthly average value does not necessarily mean that the received intensity was consistently low for the particular hour or times considered; rather it may have been zero for many days and high for a few days. The original data show this, but the fact is obscured by taking an average which, however, appears to be the most practical way of presenting the data.

Reception of radio station WWVH on 5 Mc at Adak is shown for twelve months in Fig. 1, where signal intensity is plotted for each hour. The lower portion of Fig. 1 shows the times of sunrise and sunset at station WWVH and Adak for the twelve months of the year. It will be noted that the 5-Mc reception is best during the hours of darkness, which are shown shaded in the lower part of the figure. This is in agreement with the well-known absorption effect which makes 5 Mc useful only for a few hundred miles during daylight, but useful a few thousand miles at night. The cause of the low values of signal intensity for June and July is not known, but is thought to be an absorption effect.

Reception of radio station WWVH on 10 Mc at Adak is shown for twelve months in Fig. 2. It will be noted that for November, December, January and February, reception is best for a period of

Table I

CAA Data Taken from CRPL Report Forms

Locality	West Coast					Alaska					Pacific Islands				
Frequency, Mc	5	10	15	No.	%	5	10	15	No.	%	5	10	15	No.	%
Better	182	187	124	493	20.0	1708	2044	1993	5745	67.2	549	787	873	2209	87.6
Worse						11	68	40	119	1.5					
Same	464	798	704	1966	80.0	523	1110	1042	2675	31.3	71	115	128	314	12.4
Totals	646	985	828	2459		2242	3222	3075	8539		620	902	1001	2523	

Table II

FCC Data Taken from CRPL Report Forms

Locality	East of Rocky Mts.					West of Rocky Mts.					Fort Hase, Oahu, T.H.				
Frequency, Mc	5	10	15	No.	%	5	10	15	No.	%	5	10	15	No.	%
Better	13	23	45	81	2.4	121	125	106	352	29.9	157	86	17	260	54.6
Worse	2	7	8	17	0.6	1	0	1	2	0.2					
Same	1005	1256	953	3214	97.0	215	319	288	822	69.9	27	84	105	216	45.4
Totals	1020	1286	1006	3312		337	444	395	1176		184	170	122	476	

a few hours starting a couple of hours before sunset. The curve for March shows an extension in the number of hours to about eleven when reception is useful. Reception in April was useful about $15\frac{1}{2}$ hours. In May reception began about $1\frac{1}{2}$ hours later than in April and dropped off $\frac{1}{2}$ hour earlier. June, July, September and October showed reception consistently weak and unusable.

Reception of radio station WWVH on 15 Mc at Adak is shown for twelve months in Fig. 3. It will be noted that for November, December, January, February and March the hours of reception were approximately those when 5 Mc was not received. The curve for April shows a tendency for improved reception during previous silent hours, but reduction in signal intensity after daybreak. The months of May, June, July and August showed excellent reception throughout the 24 hours. September and October show a lowering of signal intensity presumably leading to curves similar to the November, December curves previously mentioned.

Strongest reception of radio station WWV on 20 Mc at Adak was obtained during January, for which the curve is shown in the lower corner of Fig. 3. During the other eleven months for which data were submitted, the station was not heard or the intensities were much below the curve shown for January.

Examination of the data given in the three sets of curves for station WWVH shows that for almost any hour in the twenty-four at least one of the three frequencies was heard with an intensity of 3 or higher. Exceptions were poor reception in April for a few hours after sunrise and in September for a few hours before sunrise. Two frequencies were available a large portion of the time, and three frequencies were heard with high intensity part of the time.

4. Anchorage, Alaska, Data

Data on the percentage of time the transmissions of WWVH and WWV are at a useful intensity were submitted by the Radio Propagation Field Station, Anchorage, Alaska, for each month from June 1949 through March 1950. Data for the first three months were presented in a previous paper[7] and are included in the present report to give a 10-month reception picture. The observations were made hourly from 1500 or 1700 UT to 0900 or 1100 on 5, 10 and 15 Mc, and varied from 10 to 31 observations per month for each hour. Data for some hours of some months were quite similar, so that mean values were plotted for such times and the curves were appropriately marked. Curves not marked are either average values for the 10-month period or for that portion of the period not covered by other curves.

7/ Coverage of Standard Frequency Station WWVH, March-October, 1949, E. L. Hall. Report CRPL-8-4, Dec. 28, 1949; Television Eng. 1, No. 8, 16-18; No. 10, 20, 27, 1950.

Fig. 4 shows the 5-Mc reception at Anchorage of both WWVH and WWV with times of sunrise and sunset at the three localities plotted for each month. Reception for June appears to have been quite satisfactory. WWV came in earlier and with greater intensity than WWVH, as sunset is from 4 to $5\frac{1}{2}$ hours earlier at WWV. It will be noted that beginning with June, reception comes earlier each month through January, except for October, and then comes later each month. The data for September indicate greater intensity than for the succeeding month so that they do not fall in line with the other data.

The curves for 5-Mc reception of WWVH are similar to those for WWV, but reception occurs later. Accordingly it is useful for a shorter time than WWV (9 hours versus 13 hours for WWV in January).

Fig. 5 shows the 10- and 15-Mc reception at Anchorage. The 10-Mc reception from WWVH seems to be more variable with season than that from WWV. There is a definite increase in the hours of reception of WWV beginning with June and extending until January, when the reception period begins to decrease.

The upper curves of Fig. 5 show the 15-Mc reception at Anchorage. Seasonal effects are apparent. WWVH appears to be useful for a longer period in the day than WWV.

5. <u>Data from Los Angeles, California</u>

An observer in Los Angeles, California, made a large number of observations of reception of WWVH and WWV from late March through September, 1950. These observations provided data except for the late evening and early morning hours. As there appeared to be very little seasonal change, all data were averaged and curves plotted for the different frequencies of WWV and WWVH against hours UT as in Fig. 6. Times of approximate sunrise and sunset are also shown for the two stations and Los Angeles for the period under consideration.

Referring to the curves for 5 Mc, it is seen that WWV comes in before sunset at Los Angeles and reaches a maximum after dark. WWVH comes in about three hours later. It presumably maintains a strong signal throughout the night until an hour after daylight, as it is still night at the station. WWV's signal, however, was zero because of the earlier sunrise at WWV. Los Angeles is beyond the reach of the 5-Mc transmissions during most of the daylight hours, being approximately 2300 and 2500 miles from WWV and WWVH, respectively.

The 10-Mc transmissions of WWV are usable in Los Angeles most of the time except for a period of about nine hours starting about an hour after sunrise. WWVH's 10-Mc transmission is similar except the unusable period starts an hour or so later.

The 15-Mc transmissions of WWV have greater intensity than those of WWVH. This is not surprising when one considers that the powers have a ratio of 22:1 and the distances are similar. The curves indicate that WWV's 15-Mc transmission is useful during the daylight hours when the 5 and 10-Mc transmissions are not received satisfactorily.

Curves for WWV's 2.5 and 20-Mc transmissions are shown at the top of Fig. 6. Unfortunately data are lacking to show how long the 2.5-Mc transmission is received after dark. However, it is probable that it can be received as long as most of the transmission path is in darkness. This transmitter has 0.7-kw output. The 20-Mc transmission was received during daylight hours, but is less dependable than at the lower frequencies.

6. Data from South Australia

Observations were made by an individual for ten months on the reception of stations WWVH and WWV on 5, 10 and 15 Mc at Huddleston, South Australia. Some of the data were given in the previous report showing reception from July to October, 1949. The data received since that time are presented in Fig. 7 where signal intensity on a 0-9 basis is given for the two stations and three frequencies on a 24-hour basis. The lower part of the figure shows the sunrise and sunset times (UT) for Huddleston, WWVH and WWV. It was convenient to divide most of the data into two periods, October, 1949, to February, 1950, inclusive, and May to August 1950. Data for March and April, 1950, were not supplied. Averages were accordingly determined and plotted as shown in the figure. The 15-Mc August data were so radically different from those for May, June and July that a fifth curve was plotted.

Examination of the 5-Mc curves for WWVH shows no seasonal difference. Reception begins near sunset at Huddleston and drops out about the time of sunrise at the transmitter. The 5-Mc transmission from WWV shows a 2-hour difference in the building up of signal intensity with the May-August signal coming in earlier. This is because of the earlier sunset at Huddleston for these months. The most intense signals from WWV are received during the two hours when the transmission path is in darkness. The transmission path from WWVH is in darkness from six to seven hours during which signals from WWVH are heard. The signal intensities on 5 Mc are below those on the higher frequencies and the data demonstrate the futility of this frequency for day transmissions over long distances, and its dependence upon darkness over the transmission path for reception at great distances.

The 10-Mc curves of Fig. 7 show much higher field intensities than the 5-Mc curves and also a seasonal effect. WWVH's intensity increased from zero following sunset at the transmitter and maintained a strong signal during the hours of darkness at Huddleston when observations were made. It was not heard during the morning and early afternoon hours.

WWV's reception shows two periods of increased intensity with periods of nonreception in between. WWV begins to come in a few hours before sunset at Huddleston (night at transmitter), reaches a maximum and slowly falls to zero a few hours after sunrise at the transmitter (night at Huddleston). It is again heard with lesser intensity for a few hours, part of which have a daylight path.

The 15-Mc curves for WWVH show a more intense signal for the October-February period than for the May-August period. Signal intensity of S5 or higher is seen to be available for 10 hours for the former period and about 6 hours for the latter.

The 15-Mc October-February curve for WWV shows maximum intensity soon after sunset at the transmitter (morning at Huddleston), falling to zero in about 5 hours. The intensity built up again and held at a low value as long as the observations were continued(until about midnight). The May-July curve shows greater intensity over a longer period with the peak occurring 17 hours earlier than in the October-February period. A signal intensity of S5 is available for about $3\frac{1}{2}$ hours. The curve for August builds up to S5 for an hour but much of the remaining time has less intensity than in the May-July period.

If an intensity of S4 is taken as a minimum for reception, it is seen that the 5-Mc transmissions are not satisfactory. However, the 10 and 15-Mc transmissions are useful a considerable part of the day. The advantage in having station WWVH is evident from the curves and the following Table 3. The difference between the total hours shown and hours for WWV indicates the improvement in reception because of WWVH.

7. Data from Kingston, Jamaica

Data were submitted on a QSA5 basis for reception of WWV and WWVH as observed by an individual at Kingston, Jamaica. Observation times were 7:00 a.m., 1:00 p.m., and 7:00 p.m., EST, which is the same as Jamaica time. The period covered was from February through November, 1950. The data for each frequency from each station were averaged for each month and are presented in Table 4. Kingston is about 1470 miles from WWV and 5200 miles from WWVH. Trial observations on 5 Mc at 1:00 p.m. were without success, as daylight paths existed for both transmissions.

The 5-Mc transmission from WWV at 7:00 p.m. showed a maximum intensity when sunset had occurred at WWV and Kingston an hour or more before the measurements. The data are given in Table 5. As the sunset occurred later in succeeding months at WWV and the measurements were made nearer and nearer sunset time, the signal intensity dropped, but increased again as the sunset became earlier at WWV. The 7:00 a.m. measurements were made after sunrise for both points and showed a rather low signal intensity.

The 5-Mc transmission from WWVH was received with low intensity at 7:00 a.m. It was daylight in Kingston but night at WWVH. The signal intensity averaged about QSA1.

Table 3

Hours per Day with Average Signal Intensity S4 or Higher at Huddleston, South Australia

Frequency, Mc	Season	WWVH	WWV	Total
5	-	0	0	0
10	Oct.-Feb.	10½	7	10½
	May-Aug.	10	9½	12½
15	Oct.-Feb.	11½	2½	14
	May-Aug.	8½	-)	
	May-July	-	6½)	9½
	August	-	3½)	

Table 4

Average Estimated Signal Intensities of WWV and WWVH at Kingston, Jamaica, February to November, 1950. (QSA-5 basis)

Freq. Mc	Station	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
				1200 UT (7:00 a.m. EST)							
5	WWV	1.2	2.7	2.0	1.6	1.8	1.4	1.4	1.5	1.5	2.2
5	WWVH			0.8	1.1	1.2	1.1	1.0	1.1		
10	WWV	4.2	4.8	4.6	4.7	4.9	4.8	4.7	4.6	4.2	5.0
10	WWVH	2.2	3.2	3.6	3.4	3.7	3.9	3.8	3.3	3.3	1.7
15	WWV	3.9	3.9	3.8	3.3	3.6	3.2	3.0	3.1	2.9	3.8
15	WWVH	1.7	1.8	2.1	2.2	2.4	2.2	2.0	1.3	1.4	0.6
				1800 UT (1:00 p.m. EST)							
10	WWV		3.6	3.6	2.5	2.8	3.7	3.5	3.1	2.8	3.8
15	WWV		4.4	3.8	3.4	4.0	3.3	3.3	3.3	3.8	4.3
				0000 UT (7:00 p.m. EST)							
5	WWV	2.9	3.5	2.3	1.7	1.9	1.7	2.2	2.9	3.4	3.6
10	WWV	4.7	4.9	4.6	4.9	4.9	4.7	4.7	4.6	4.5	4.5
10	WWVH	3.1	2.4	2.4	2.0	1.5	1.0	0.9	1.4	1.5	1.4
15	WWV	4.5	4.2	4.0	3.8	3.6	3.2	2.7	2.2	1.4	1.7
15	WWVH	2.6	2.0	1.8	1.8	1.8	1.3	1.1	1.0	0	0

Table 5

Average Estimated Signal Intensity of WWV 5 Mc at Kingston, Jamaica, at 0000 GCT (7:00 p.m. EST) Showing Effect of Sunset Times on Signal Intensity

Month 1950	Average Sunset, Hours UT Kingston	WWV	Difference between Aver. Sunset and Time of Meas. Hours	Average Sig.Intensity (QSA Scale)
Feb.	22.9	22.8	1.2	2.9
March	23.1	23.2	0.9	3.5
April	23.2	23.8	0.5	2.3
May	23.4	0.2	0.2	1.7
June	23.6	0.5	0	1.9
July	23.6	0.5	0	1.7
Aug.	23.4	0	0.3	2.2
Sept.	23.0	23.2	0.9	2.9
Oct.	22.6	22.5	1.5	3.4
Nov.	22.3	22.0	1.9	3.6

The data indicate that the 10-Mc transmissions were stronger than the 15-Mc transmissions for both WWV and WWVH, but WWV was stronger than WWVH, as would be expected.

III. Reception of Other Standard Frequency Stations

1. Observations of 5-Megacycle Standard Frequency Transmissions from JJY, Tokyo, and WWVH, Maui, Hawaii.

About 1000 observations were received from the U.S.Navy's Communication Station at Guam on the 5-megacycle standard frequency transmissions from radio station JJY, Tokyo, Japan, and WWVH, Maui, Hawaii, covering the period November 26 through December 7, 1949.

Station JJY was operated with a power of 1 kw on 5 Mc for the period from 0058 UT November 18 to 0700 UT December 8, 1949, under sponsorship of the Supreme Commander, Allied Powers. Each hour of the twenty-four was made up of the following emissions and silent periods:

0-10, 20-30, 40-50 minutes, 1000-cycle modulation
10-18, 30-38, 50-58 minutes, off the air
18-20, 38-40, 58-60 minutes, voice announcements, call letters, in Japanese and English.

Station WWVH was operated with a power of 0.4 kw on 5 Mc practically continuously during the period of test except for the following regular interruptions: each hour, 0-4, 30-34 minutes, off the air; each day, 0700-0734 and 1900-1934 UT, off the air. Station WWV, Beltsville, Maryland, operated continuously, but as it is 8000 miles from Guam, its 5-Mc transmissions were probably received there with low intensity.

The time schedule used by JJY was excellent to enable observers to monitor JJY and WWVH together and separately. The data consisted of from 80 to 90 observations per day for 12 days, reported on the signal intensity using the QSA5 scale. They were plotted for each day with respect to time, and an average was obtained for each hour. Station JJY was approximately 1600 miles from Guam, while WWVH was about 4000 miles eastward. The records stated that on some days JJY's 1000-cycle tone "blocked out WWVH completely." It is believed that suitable directional antennas would enable either JJY or WWVH to be received satisfactorily at Guam during hours of darkness, as the two transmission paths for these stations are practically at right angles.

The average received signal intensities for JJY and WWVH were plotted versus time in Fig. 8. Hours of darkness (sunset to sunrise) were also shown for Guam and the two radio stations. The correlation between the signal intensities for 5 Mc and the hours of darkness is well shown. The distance from Guam to WWV is about 8000 miles, which is too great for reception of 5 Mc. However, the hours of darkness at WWV are also plotted to show that there is no correlation as exists for the two closer stations.

Many other observers in the United States spent time endeavoring to monitor JJY, but without much success. This was partly because of erroneous announcements of transmission schedule. However, examination of the chart of darkness hours for JJY and WWV indicate that the most likely time to have heard JJY on the west coast was from about 1200 to 1500 UT. WWV would be dropping out on 5 Mc about 1200 and for three hours JJY might have been heard. Localities farther east would have had less time for successful monitoring.

A large number of observations were made at many localities in Japan during these special transmissions. The results were made available through the Department of the Army. A high noise level prevails in Japan so that reception of WWV is unreliable and WWVH is heard consistently only a few hours of the night. The efforts in Japan were therefore largely directed to measurements of signal intensity, noise and interference at the various observation points. When WWVH was observed its intensity was far below that of JJY being from 3900 to 4600 miles from the Japanese observation points. The greatest distance of the Japanese points from JJY was about 600 miles. Conclusions were drawn in the report that JJY's 5-Mc transmission was adequate for a 125-mile radius, both day and night, but beyond this afternoon field intensities were unreliable.

These conclusions seem somewhat restricted in terms of data which have been obtained with station WWV and other results reported for WWVH.

The prevailing noise level and other interference at a given location or in a given region are the chief limiting factors in reception at this frequency and hence extremely limited coverage may result. Others of the well-known factors affecting reception may also play a part, so that any estimates or predictions of results to be expected at a given locality are subject to change in accordance with experimental results at that location. From hitherto unpublished results on certain special transmissions of WWV in 1935-6, during the day, 50% intelligibility of disconnected words was obtained up to 230 miles in June, August, and September, and up to 560 miles in December, using 1 kw of power. WWVH is heard several thousand miles at night. It appears that the Japanese area is plagued with a natural interference barrage in addition to the interference from many stations which do not adhere sufficiently to international frequency assignments. One recording of WWVH and JJY on 5 Mc in Japan showed a beat frequency between the two stations at times. Agreement between the stations was better than a part in 10^7 for a period of seven hours. In the following two hours WWVH's frequency was indicated different by as much as 9 parts in 10^7, but in a random manner. The sunrise or sunset period at a control point in the radio propagation path should be avoided if highest accuracy is desired. As the ionosphere layers begin to change in height with the coming of daylight or darkness the transmission path is altered, resulting in fluctuations in the received frequency known as the Doppler effect. It is therefore evident that small beat frequencies may be introduced in spite of maintaining two stations very precisely in synchronism and may be detrimental to some users of WWV and WWVH.

The frequency of the audio modulation also changes by small amounts, sudden phase shifts being quite noticeable when monitored against a steady local source. Reception of the same audio frequency from two stations at about the same intensity, when the Doppler effect is in evidence, would make use of the audio frequency difficult. In such a case it would be desirable to use a directional antenna, if possible, to cut out reception of the station showing the greater change. Otherwise monitoring of the standard audio frequency would have to be greatly prolonged in order to average out the frequency changes and obtain a more accurate value.

2. Standard Frequency Transmissions from MSF, Rugby, England

The Federal Communications Commission submitted reports from twelve of their field offices scattered throughout the United States and one office in Hawaii covering reception of the English standard frequency station MSF, England, operating approximately half an hour each day on 5 and 10 Mc with a power of 10 kw. The time and duration of these transmissions were such as to afford a minimum of interference with WWV and WWVH transmissions and are shown in Fig. 9. The detrimental effect (if any) of three standard frequency stations operating simultaneously on the same frequency was accordingly more difficult, if not impossible, to evaluate.

The MSF 5-Mc transmission was as follows:5/

0544 UT	for one minute, call letters, voice announcement;
0545	for five minutes, 1000-cycle modulation;
0550	for nine minutes, carrier only;
0559	for one minute, call letters, voice announcement;
0600	for five minutes, 1000-cycle modulation;
0605	for nine minutes, carrier only;
0614	for one minute, call letters, voice announcement.

The MSF 10-Mc transmission was divided in a similar manner, with the first announcement beginning at 0629 UT and the last one at 0659 UT. For American observers these transmissions came between the hours 0044 and 0200 am, EST, or 0944 and 1100 pm, PST. The call letters and voice announcements came at the same time as the announcements of WWV and WWVH. The 1000-cycle modulation was on at the same time as the 440- or 600-cycle modulations of WWV and WWVH. When MSF was heard the 1000-cycle modulation could be distinguished along with the modulation from WWV. The periods with the carrier only apparently were not heard, so contributed to rather meager reports of reception. The distance range involved for continental United States was from approximately 3300 to 5500 miles.

The 5-Mc transmissions were heard faintly in Massachusetts, Georgia, Michigan, Texas and Idaho. Georgia reported the 10-Mc transmission usable on three days, and the other eleven U.S. localities reported various degrees of weak reception from "1000-cycle modulation heard, but voice not understandable" to "heard very weakly and unusable with WWV and WWVH operating." It was heard very weakly at Fort Hase,Oahu, T.H.

An observer in South Australia has heard MSF on 10 Mc a number of times during May, July and August. His rating of signal intensity for MSF, WWV and WWVH was 2, 5, and 7, respectively.

One or two of the observers demonstrated reception of the 1000-cycle modulation on an oscilloscope while WWV had its 440 or 600-cycle modulation on. Other observers were sure of the identity of the station only during the portion of a minute when WWV was silent.

In view of the above reports there seems to be very little use in making further observations in the United States on MSF under its present limited time schedule. It would appear that the 5-Mc transmissions should have been received more strongly than reported, as they had an all-darkness transmission path to the United States. Reception for a half-hour period might be difficult because of local conditions, but improve at a later time.

Conclusions drawn from these tests at this time are that MSF does not interfere with stations WWV or WWVH as used in the United

States. What the conclusions may be for observations in the British Isles, Europe and Africa are unknown, but in any event, it would appear that the times of transmission are too short to evaluate them in terms of a world-wide standard frequency service.

IV. Discussion

Most of the reports of reception of WWVH and WWV indicated no measurable beat between the carrier frequencies or audio frequencies as broadcast, so that no detrimental effects were noted caused by operation on identical frequencies. However, it is probable that very few of the observers had facilities for the determination of a small frequency difference if such existed. It should be noted that very precise measurements and adjustments were made twice daily at WWVH[8/] in terms of WWV so as to maintain the seconds pulses and frequency in synchronism. Special precautions were taken in this work which are not usually necessary except in work of highest accuracy.

Observers in Government agencies such as the Federal Communications Commission had facilities for measurements of small frequency differences. A report from the Postmaster General's Department, Commonwealth of Australia, for the five monitoring centers, Perth, Adelaide, Melbourne, Sydney, and Brisbane, indicated no interference between WWVH and WWV. WWV is about twice as far distant from these cities as WWVH, being almost half-way around the globe.

Some of the reports from a few of the FCC field stations at times indicated beat frequencies from a fraction of a cycle to 2.5 cycles for some periods on 10 and 15 Mc. Later the beat was not present. At times it was identified and disappeared when WWVH shut down for its periodic silent periods. The beat was particularly noticeable on occasions when the two stations were received with equal intensity. At other times the beat was found to drift to zero. Fading also produced a beat effect at times so that it was difficult to distinguish between the fading and a frequency difference between the stations.

Under suitable receiving conditions it is possible to receive the seconds pulses on one or two of the carrier frequencies both ways around the earth. These pulses as received seldom coincide. The pulses transmitted from WWV and WWVH are sent at nearly identical times; the two pulses will not arrive at a receiving point at the same instant if the receiving point is nearer one station than the other, as was the case for those observing this effect.

Theoretically the beat effects described above may be expected but, as some observers pointed out, their absence was surprising. Generally speaking, beat frequencies and phase shifts may be expected when receiving two widely spaced stations operating on identical fre-

8/ Adjustment of high-precision frequency and time standards, John M. Shaull. Proc. IRE 38, 6-15, January, 1950.

quencies. At times these effects may be serious and at other times non-existent. Shifting to other standard frequencies or the use of directional antennas may largely overcome undesired effects.

V. Conclusions

The data presented verify past experience with the standard frequency transmissions as to propagation characteristics. These may be briefly summarized as follows. The 5-Mc transmissions are generally useful for shorter distances during daylight and a few thousand miles at night. The 10-Mc transmissions are useful for longer distances and show no such pronounced attenuation or absorption with daylight as is manifested by 5 Mc. Directional antennas may be a necessity at some locations if satisfactory results are to be obtained. The 15-Mc transmissions are useful for distances from a few hundred to 8,000 or 10,000 miles, day or night. Seasonal effects, changes in sunspot numbers, ionosphere disturbances and local conditions of atmospheric and man-made electrical noise affect reception ranges. The data are to be interpreted in terms of a drastic change in solar activity, as evidenced by the 12-month running average Zurich sunspot number, which was 137 for June, 1949, and 68 (estimated) for November, 1950. The months from June, 1949, through July, 1950, may be considered roughly to be part of a period of high solar activity, whereas the months beginning with August, 1950, represent medium solar activity. There was a sharp decline in the monthly average Zurich numbers beginning with September, 1950. The effect of decreased solar activity is in the direction of a lowering of critical frequencies and, almost without exception, optimum traffic frequencies for a given transmission path. Results to be expected at a given location on the several standard frequencies may be estimated from the information given herewith. The best frequency or frequencies can be determined by trial.

Station WWVH has been in operation for a period of two years on an experimental basis with low power. It has been found to supplement the standard frequency and time service coverage of station WWV, particularly in the Pacific and Alaskan areas, without introducing undesirable interference. It is likely that increased power at WWVH would further extend the coverage and also give more definite data on the seriousness of beat frequencies sometimes observed.

The operation of station JJY on 5 Mc for a limited period was insufficient to get the desired experimental results; however, operation of the station would undoubtedly increase the standard frequency coverage for the Far East.

Station MSF operates on 5 and 10 Mc at such a time of day and for such a short period that its effect upon WWV transmissions is of no consequence in the United States. The effect in Europe has not been published. If the station should operate for longer periods such as for 24 hours one or two days per week, considerable interesting information could be obtained in the United States.

VI. Acknowledgment

The work of the individuals in the various agencies and elsewhere who provided the extensive data used in preparing this report is gratefully acknowledged.

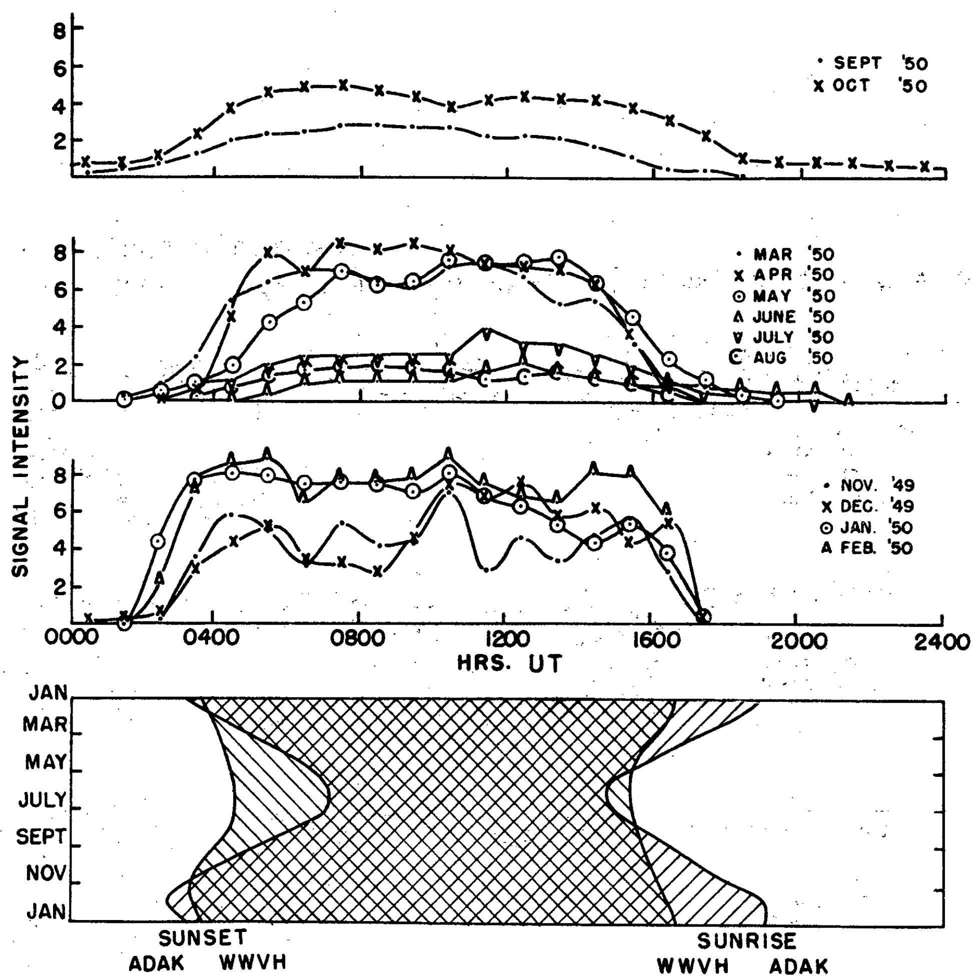

FIG. I. RECEPTION OF WWVH ON 5 MC AT ADAK, ALASKA, NOV. 1949 THROUGH OCT. 1950

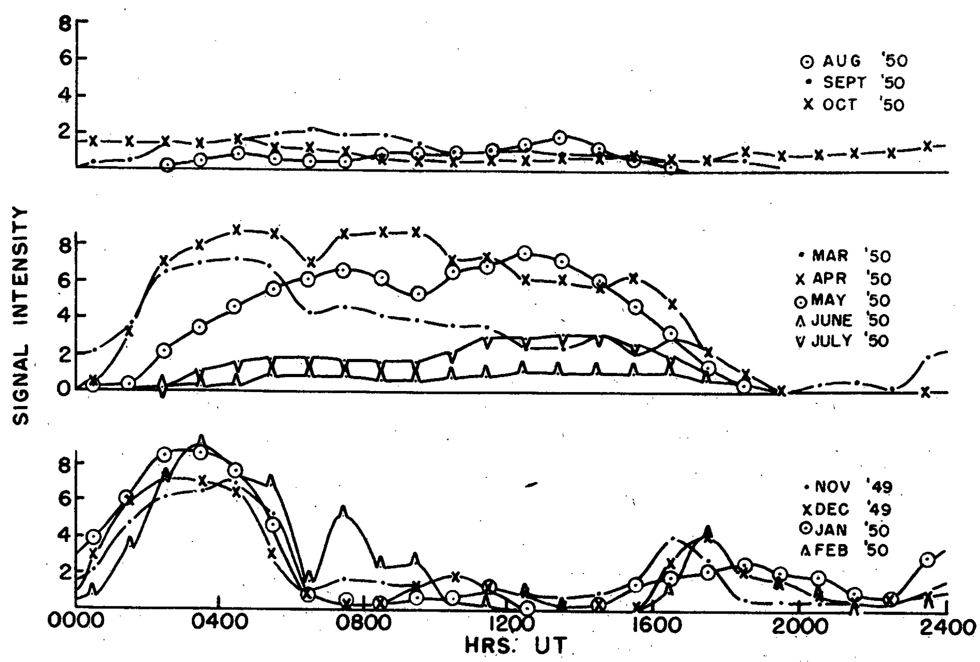

FIG. 2. RECEPTION OF WWVH ON 10 MC AT ADAK, ALASKA, NOV. 1949 THROUGH OCT. 1950

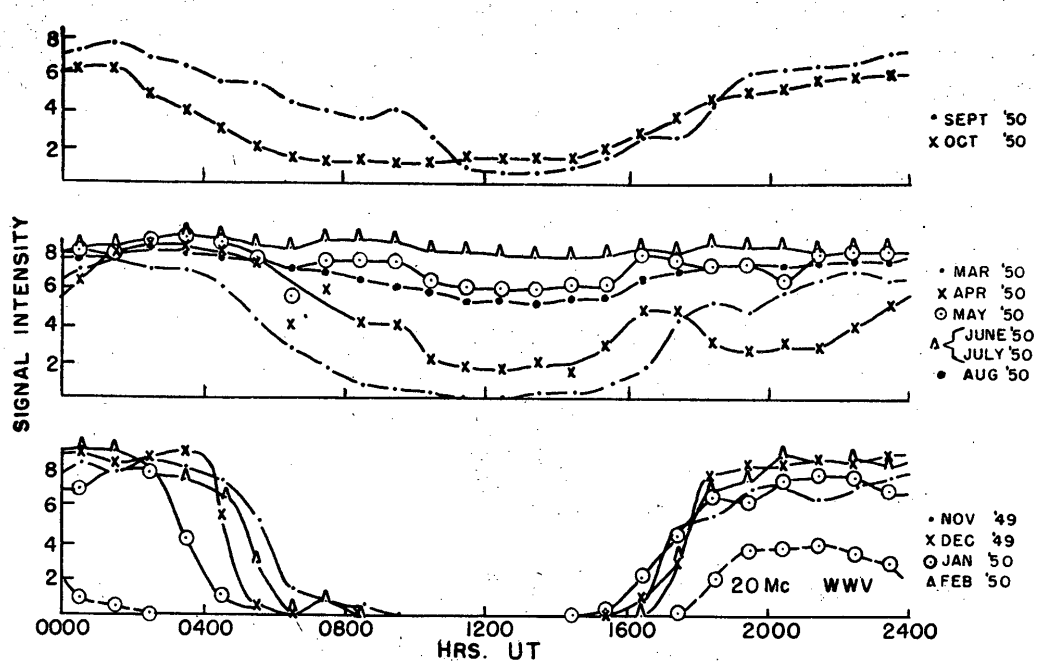

FIG. 3. RECEPTION OF WWVH ON 15 MC AT ADAK, ALASKA, NOV. 1949 THROUGH OCT. 1950 (WWV ON 20 MC JAN. 1950)

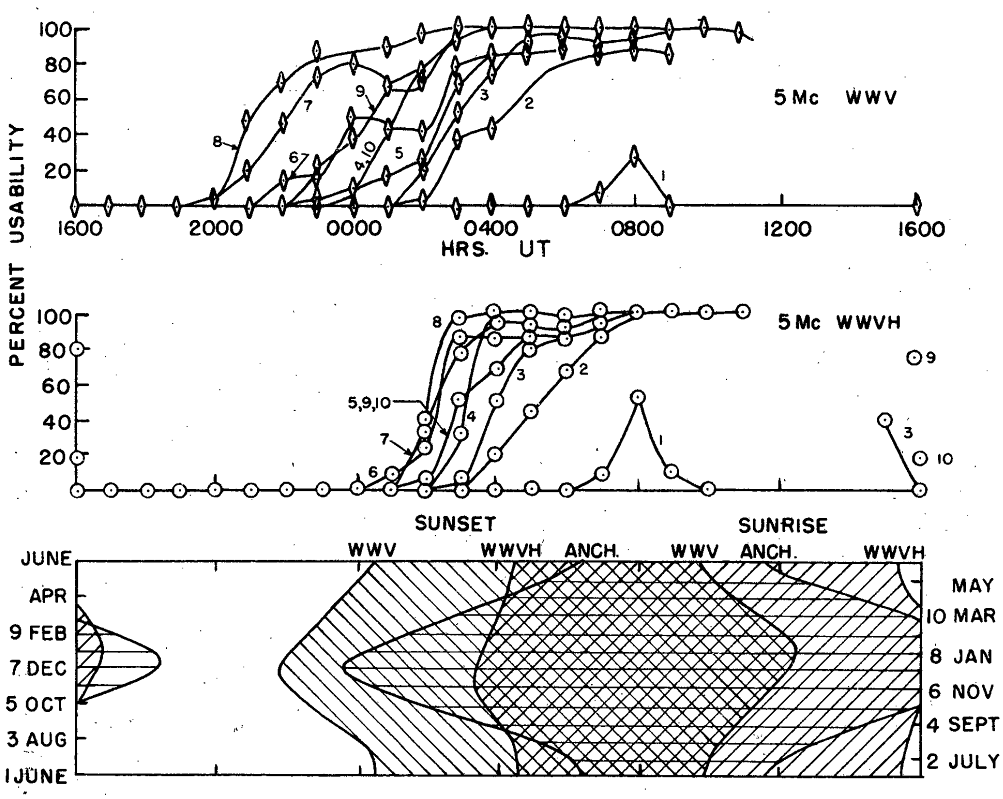

FIG. 4. 5-MC RECEPTION OF WWVH AND WWV AT ANCHORAGE, ALASKA, JUNE 1949 - MARCH 1950. SUNRISE AND SUNSET TIMES SHOWN FOR THE THREE LOCATIONS.

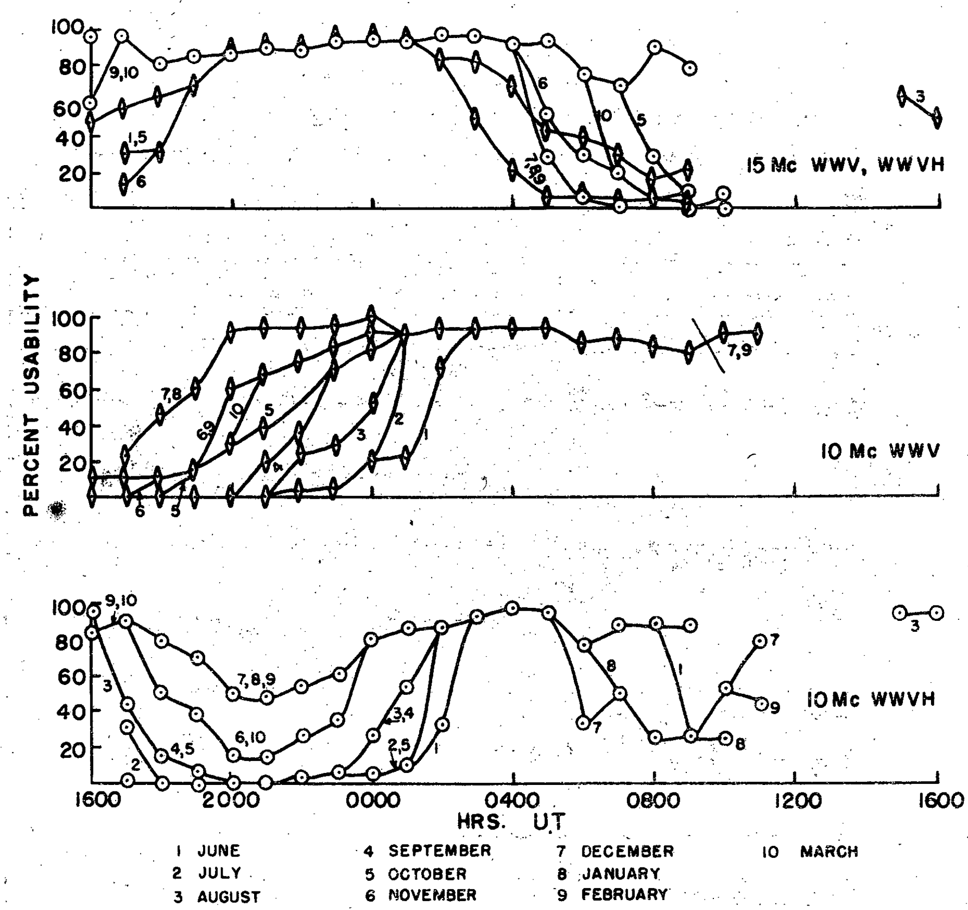

FIG. 5. 10- AND 15-MC RECEPTION OF WWVH AND WWV AT ANCHORAGE, ALASKA, JUNE 1949 - MARCH 1950.

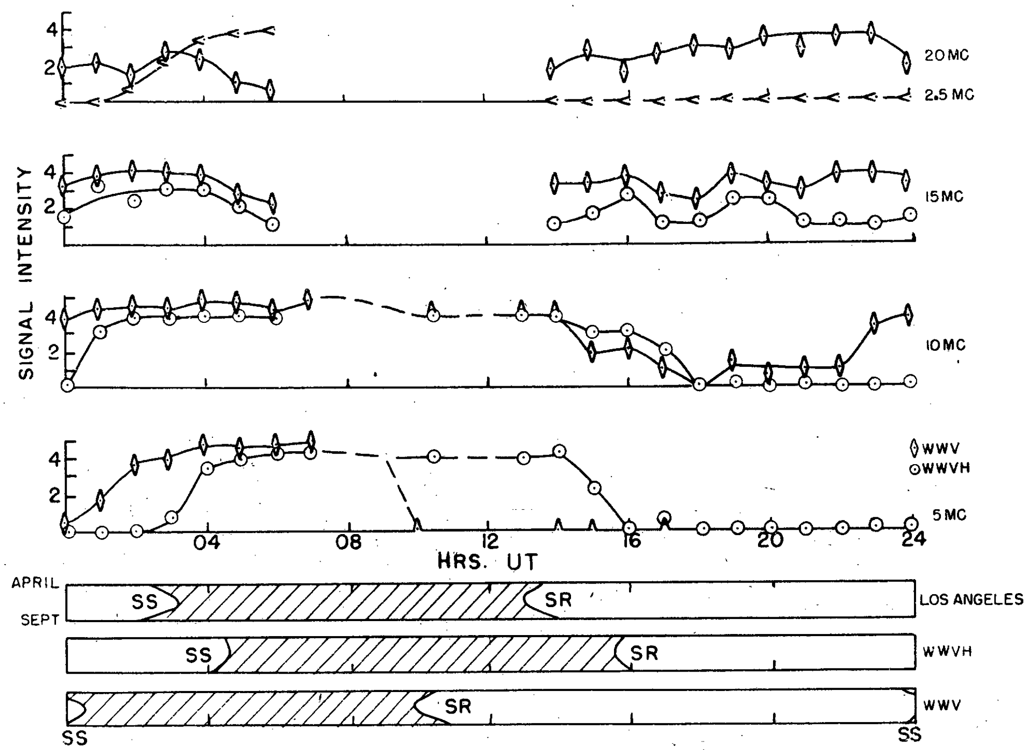

FIG. 6. CHART SHOWING AVERAGE RECEPTION OF WWVH AND WWV AT LOS ANGELES, CALIFORNIA APRIL-SEPTEMBER 1950, ON 5, 10, AND 15 MC, AND WWV ON 2.5 AND 20 MC.

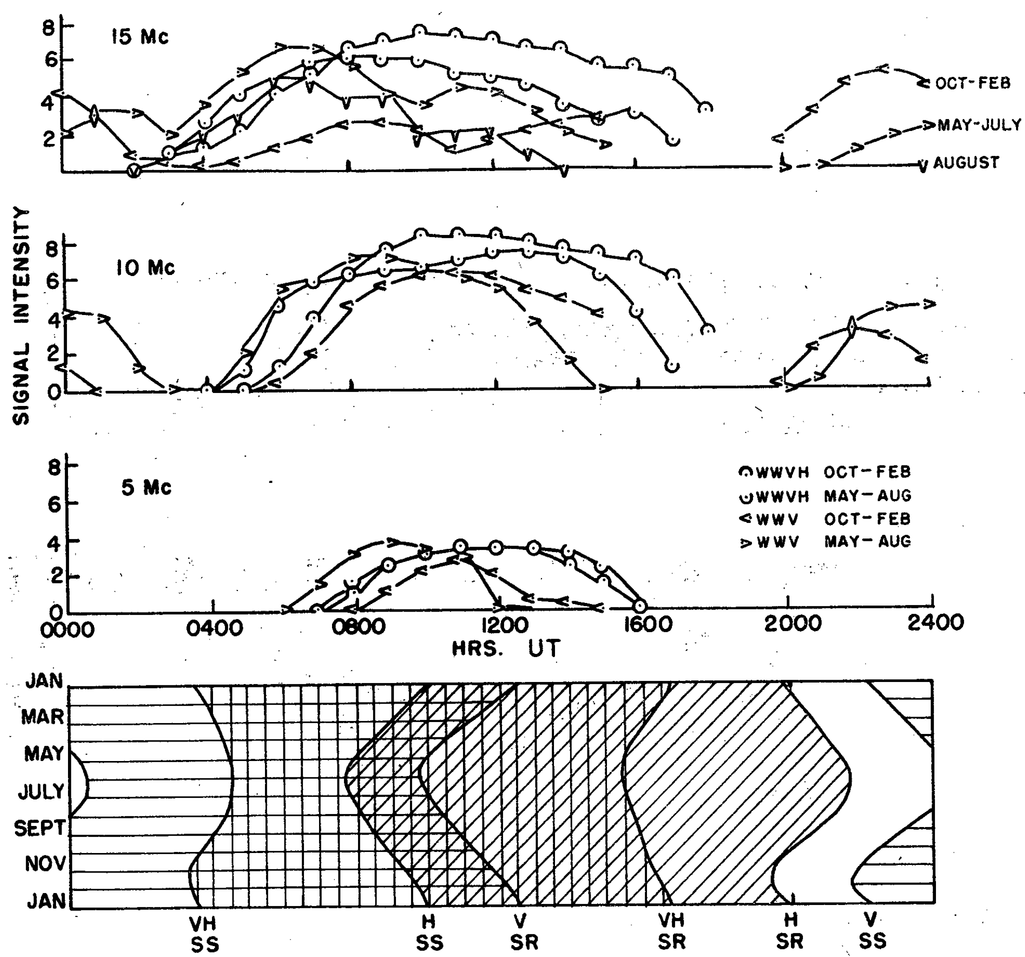

FIG. 7. RECEPTION OF STATIONS WWVH AND WWV AT HUDDLESTON, SOUTH AUSTRALIA, OCTOBER 1949 TO AUGUST 1950.

APPROX. DISTANCE HUDDLESTON TO WWVH 5600 MILES, WWV 10600 MILES

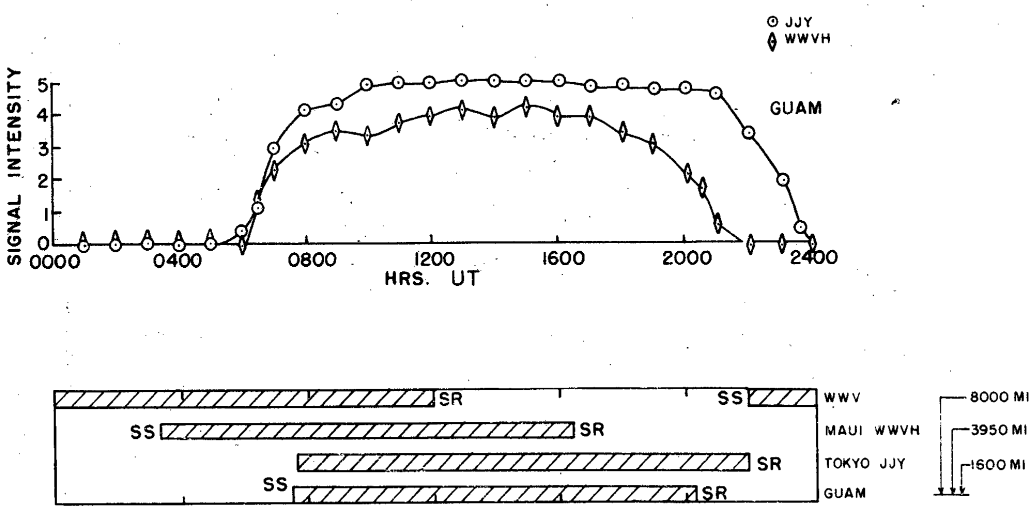

FIG.8. RECEPTION OF WWVH AND JJY AT GUAM NOV. 26 TO DEC. 7, 1949.

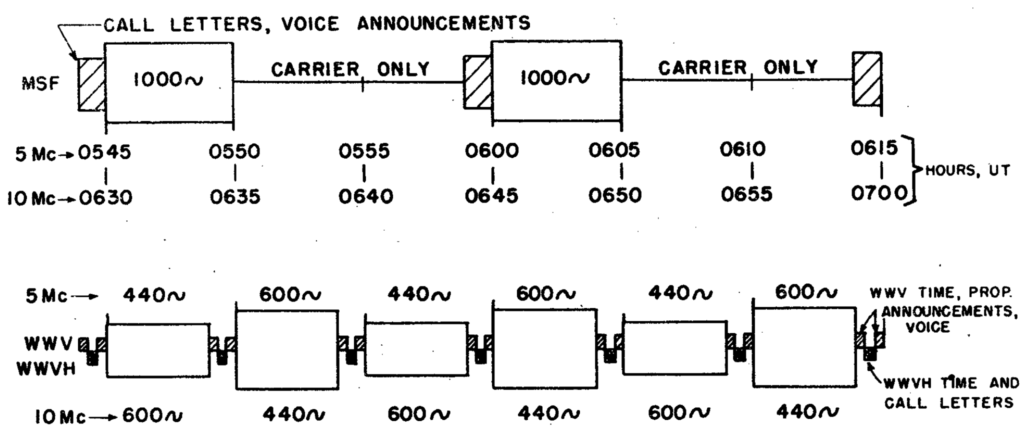

FIG. 9. CHART SHOWING STANDARD FREQUENCY TRANSMISSIONS OF MSF ON 5 AND 10 MC AND RELATION TO MODULATIONS OF STATIONS WWV AND WWVH.