WWV and WWVH Standard Frequency and Time Transmissions*

The frequencies of the National Bureau of Standards radio stations WWV and WWVH are kept in agreement with respect to each other and have been maintained as constant as possible with respect to an improved United States Frequency Standard (USFS) since December 1, 1957.

The nominal broadcast frequencies should, for the purpose of highly accurate scientific measurements, or of establishing high uniformity among frequencies, or for removing unavoidable variations in the broadcast frequencies, be corrected to the value of the USFS, as indicated in the table below.

WWV Frequency
With Respect to U. S. Frequency Standard

1960 October 1600 UT	Parts in 10^{10}*
1	−147
2	−147
3	−146
4	−146
5†	−146
6	−148
7	−148
8	−148
9	−147
10	−148
11	−148
12	−148
13	−148
14	−148
15	−148
16	−148
17	−148
18	−148
19	−148
20	−148
21	−148
22	−148
23	−148
24	−148
25	−148
26	−147
27	−147
28	−147
29†	−146
30	−148
31	−148

*A minus sign indicates that the broadcast frequency was low.

† The method of averaging is such that an adjustment of frequency appears on the day it is made. The frequency was decreased 3×10^{-10} on October 5; and decreased 21×0^{-10} on October 29.

The characteristics of the USFS, and its relation to time scales such as ET and UT2, have been described in a previous issue,[1] to which the reader is referred for a complete discussion.

The WWV and WWVH time signals are also kept in agreement with each other. In addition, they are locked to the nominal frequency of the transmissions and consequently may depart continuously from UT2. Corrections are determined and published by the U. S. Naval Observatory. The broadcast signals are maintained in close agreement with UT2 by properly offsetting the broadcast frequency from the USFS at the beginning of each year when necessary. This new system was commenced on January 1, 1960. A retardation time adjustment of 20 milliseconds was made on December 16, 1959; another retardation adjustment of 5 milliseconds was made at 0000 UT on January 1, 1960.

Notice of Time Signal Adjustment WWV/WWVH New Timing Code on WWV

In order to bring the time signals of WWV/WWVH and other stations into closer agreement, a retardation phase adjustment of the time signals radiated by WWV/WWVH is planned at 0000 UT on January 1, 1961. The retardation will be precisely 5 milliseconds.

It is expected that such adjustments in the time signals will be made as infrequently as possible and preferably at the beginning of each calendar year when necessary. The time signals are locked to the broadcast frequency.

In 1961 it is planned to maintain the frequency stable to 1 part in 10^{10} and at the same offset value as before, *i.e.*, −150 parts in 10^{10} with reference to the United States Frequency Standard.

The necessity for offsetting the frequency and for adjustment of the time signals is described in "National Standards of Time and Frequency in the United States," Proc. IRE, vol. 48, pp. 105–106, January, 1960, and "Co-Ordination of Time and Frequency Transmissions," *J. IEE*, vol. 6, no. 65, p. 268; May, 1960.

On January 1, 1961, the National Bureau of Standards will commence a regular broadcast from WWV of a timing code which gives the day, hour, minute, and second (Universal Time), and which is locked in phase to the frequency and time signals. The code is a 36 Binary Digit 100 PPS Code carried on 1000-cps modulation. A complete time frame is 1 second. The code will be broadcast for 1-minute intervals and 10 times per hour. Except at the beginning of each hour, it immediately follows the standard frequencies of 440 cps and 600 cps. The code was broadcast experimentally during the interval April to August, 1960, and is described in "Experimental Timing Code Added to WWV Broadcasts," NBS *Tech. News Bull.*, vol. 44, no. 7, pp. 114–115; July, 1960.

An announcement, "Time Code on WWV," is available on request.

National Bureau of Standards
Boulder, Colo.

*Received by the IRE, December 1, 1960.

[1] "National standards of time and frequency in the United States," Proc. IRE, vol. 48, pp. 105–106; January, 1960.

Stability Criterion for Amplifier Moving in Space*

The linear network formula for feedback,

$$A(s_1) = \frac{A_i(s_1)}{1 - H(s_2)A_i(s_1)}, \qquad (1)$$

with $s_1 = s_2 = j\omega_1$, and with $H(s_2)A_i(s_1) = 1$ designating the point of instability, can, with $s_1 \neq s_2$, be extended to cover the case when the amplifier of inherent amplification, $A_i(s_1)$, moves in space with the velocity v. The feedback path is then a radiation path with sufficient reflected power to make the stimulance, or negative resistance, compensate for the system loss.[1] To make the formula apply, we must take into account the Doppler frequency shift, and we will find that for $v \ll c$, a linear system is able to repeatedly reach the instability point at a repetition rate dependent upon the Doppler shift $2v/\lambda_1$, where $\lambda_1 = 1/f_1$ and where c is the velocity of light. We may formulate a stability criterion during any brief interval of assumed steady-state condition by means of the straight-forward network transformation

$$H(s_2) \to R_N(s_2) \to R_{N\,\mathrm{eq}}(s_1) \to H(s_1)_{\mathrm{eq}}. \qquad (2)$$

Here $H(s_2)$ is the feedback transfer function for a feedback path exposed to Doppler shift. It is interpreted as the stimulance $R_N(s_2)$ of return frequency $\omega_2/2\pi$, transformed into the equivalent stimulance $R_{N\mathrm{eq}}(s_1)$ of signal frequency $\omega_1/2\pi$. Finally, this stimulance is interpreted as a feedback factor, so that the entire system can be treated as a single frequency system. We may formulate the following criterion: *A linear feedback system, in space, with radiation type feedback and an amplifier moving with a velocity v, very much less than that of light, remains stable when the return frequency differs from the transient generated output frequency by the Doppler shift* $2v/\lambda_1$, *unless* $H(s_2)A_i(s_1) = H(s_1)_{\mathrm{eq}}A_i(s_1) = 1$, *where* $H(s_1)_{\mathrm{eq}}$ *is defined by the requirement that the corresponding stimulance covers the system loss.* The transformation, (2), implies the insertion of a fictitious frequency converter into the system, to make possible the treatment of Doppler stimulance at signal frequency. If a network element in form of a real frequency converter is inserted, as in Fig. 1,

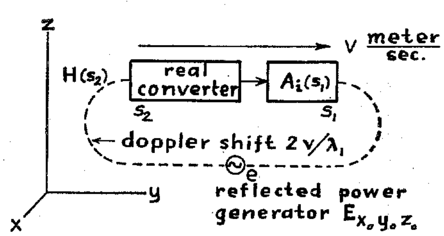

Fig. 1.

so that the return frequency becomes $(f+2v/\lambda_1)-2v/\lambda_1$, the system may oscillate much more readily, and steadily, since the intermittent operation will cease. It follows that a real frequency converter may be preset so as to substantiate oscillations at one specified Doppler shift, $2v/\lambda_1$ only, if and when this shift occurs. This phenomenon may be utilized for the control of missiles.

We may note that the instability point of the entire system above is predicted by linear network theory, including the converter, which accomplishes multiplicative mixing acting as a parametric device.

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* Received by the IRE, August 2, 1960.

[1] H. Stockman, "Communications by means of reflected power," Proc. IRE, vol. 36, pp. 1196–1204; October, 1948.