ON THE USE OF THE OMEGA NAVIGATIONAL SYSTEM AS A HIGH-QUALITY TIME REFERENCE FOR SEISMOLOGICAL STUDIES

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In some parts of the world, such as the Eastern Caribbean and Central America, one of the major drawbacks to achieving an effective clock accuracy for seismographs is the difficulty in receiving usable signals from one of the time and frequency broadcasting stations, such as WWV Boulder, Colorado. This problem applies equally to permanent seismograph stations and to temporary arrays which may be set up for aftershock studies. It is especially critical at remote stations when record change may be the only occasion in the day when it is possible for an operator to attempt a time check. Therefore, in order to be assured of the accuracy desirable for regional and teleseismic studies, it is necessary for each station, or member of an array of discrete recorders, to be equipped with an expensive high-precision (oven-controlled) crystal clock or atomic-time standard and a communications-type receiver. The initiation of the worldwide Omega low-frequency navigational system (see Burhans, 1974) offers a solution to this problem which requires only the most elementary radio receiver and digital clock circuitry at the seismograph.

Omega is being built up to provide a worldwide navigational system whereby position is determined from the phase relationships of three frequency transmissions from different base stations around the globe. Eight stations are planned for the complete network: Norway, Trinidad, Hawaii, North Dakota, Japan, Reunion, Argentina and Australia; the first five stations are already in operation Each station transmits three frequencies (10.2 kHz, 11.33 kHz and 13.6 kHz) in a sequence synchronized with the other stations of the system (Figure 1). Transmissions are repeated every 10 sec, but there is no identification or coding with which to identify the signal, except for its frequency and duration. The timing of a particular station's transmission is derived from a local caesium-beam atomic standard clock having a tolerance better than ± 7 parts in 10^{12}; the transmissions are accurate to better than 1 μsec/week against Coordinated Universal Time (U.T.C.). At the present time Omega has a 4-sec lead on U.T.C. as the system has not incorporated the latest four leap seconds. Within the Caribbean region (and generally up to ranges of 1,000 km) the 10 kW signals from Omega Trinidad swamp the transmissions of the other stations.

Because of the vital nature of any worldwide navigation aid, down time on the Omega system is supposed to be less than 0.02 per cent in a year for a given station, or for a worst-case condition, a transmitter might be off the air for up to 3 hr while repairs are effected.

In regions where a good Omega signal is available, a simple receiver can be used to pick up the transmissions. Burhans (1974) gives the circuit of a dual-gate MOSFET pre-amplifier, for use with a whip or blade-type antenna which drives a two-stage block of ceramic filters tuned to the Omega frequency. The output of this filter stage is passed to a limiter-detector circuit which is available in integrated circuit form. From this circuit the DC envelope is output; this can be detected and cleaned up to produce the reference pulse for the digital clock. There will be a small delay between real transmission start time and detection time due to the signal rise-time properties of the receiver; this delay has been measured in Trinidad and is about 6 msec on average for the rise from zero signal to full amplitude, and 12 msec for the worst case. The detection level can be varied according to the noise level prevailing and in favorable conditions rise times of less than 1 msec are possible. In any event this delay is a constant factor of each transmission and does not constitute a cumulative error in the clock; it is negligible in terms of acceptable seismological accuracy.

START — 10 SEC — START

	0·9	1·0	1·1	1·2	1·1	0·9	1·2	1·0	0·9	
* NORWAY (A)	10·2	13·6	11·33						10·2	kHz
* TRINIDAD (B)		10·2	13·6	11·33						"
* HAWAII (C)			10·2	13·6	11·33					"
* NORTH DAKOTA (D)				10·2	13·6	11·33				"
REUNION (E)					10·2	13·6	11·33			"
ARGENTINA (F)						10·2	13·6	11·33		"
AUSTRALIA (G)	11·33						10·2	13·6	11·33	"
* JAPAN (H)	13·6	11·33						10·2	13·6	"

0·2 SEC

FIG. 1. Timing and sequence of transmissions from the worldwide Omega stations. Stations marked with an asterisk are already operating. (Taken from Burhans, 1974.)

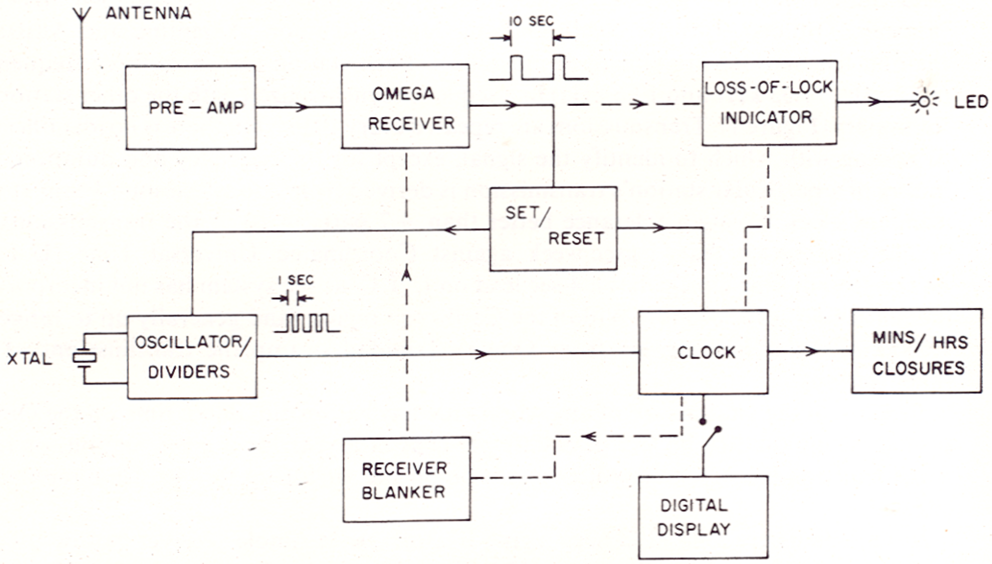

FIG. 2. Block diagram of the Omega-synchronized seismograph digital clock. The loss of lock indicator and receiver blanker circuits are optional to the main scheme.

The mode of operation of the Omega-synchronized seismograph clock may be seen from the block diagram, Figure 2. At the start of a cycle, 1-sec pulses are generated by the crystal oscillator and count-down circuitry to drive the main clock counters (for elapsed seconds, minutes and hours). By the time 10 sec have elapsed there will be some small error (lag or lead) due to the basic inaccuracy of the simple oscillator. However, a pulse from the Omega receiver can be used to set the binary circuits of the unit seconds counter to zero, corresponding to the multiple of 10 sec reached, thereby removing the error. This applies if Omega time equals U.T.C., but if Omega remains 4 sec faster than U.T.C., it is a simple matter to arrange for the circuitry to reset the unit seconds binary count to 6. For as long as the Omega pulses are received the seismograph clock will remain within a few milliseconds of U.T.C. A reset pulse, given by the Omega signal, is also applied to the 1-sec count-down circuits so that each new 10-sec period will start from a zero count.

In the (hopefully) unusual event that the Omega signal is lost, the crystal oscillator will free-run until the signal is restored During this down-time the drift of the crystal clock must not exceed ± 0.5 sec or else the clock will be 1 sec out of step when the signal returns; assuming a failure lasting 3 hr, such accuracy is well within the capability of the most elementary crystal oscillators (without ovens) which can exhibit tolerances of better than ± 0.5 sec/day. If this down-time is exceeded then the error involved would approach the 0.1-sec standard of seismology, but it is expected that this would be a very rare event.

Electrical power requirements for the circuitry can be minimized by the use of complementary metal-oxide semi-conductor ICs and by using multiplexed seven segment Ga-As digital displays; the technology of these devices is now commonplace. With the displays off, overall consumption (about 100 mW) may not be as small as for some digital clocks, but this is the sacrifice that has to be made to obtain an atomic-standard time reference for the long-term; and even so, such extra power is only a small part of the total required for the drum motors, amplifier and filter circuits of a conventional recorder.

Some refinements to the basic circuitry might prove desirable. For example, where signal strengths from two or more Omega stations are similar, it might be necessary to use a receiver blanking circuit to avoid triggering by the wrong transmission. The 200 msec gap before each Omega frame (Figure 1) makes it a simple matter to gate the receiver accurately using a suitably decoded elapsed time from the count-down circuitry (for example 9.9 sec). It would then only be necessary to pick the better signal when the station is being set up. For a status check a bistable circuit, triggered by the absence of an Omega pulse during the normal time interval for reception (9.9 to 10.1 sec), can store a loss-of-lock condition, indicating this by lighting a small LED.

The seismograph clock described derives its high accuracy from the intrinsic accuracy of the Omega navigational system. Further testing and development is being conducted with a view to implementing the advantages of this system at the Eastern Caribbean stations of the Trinidad network.

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Reference

Burhans, R. W. (1974). Phase-difference method offers low-cost navigation receivers, *Electronics* **47,** 98–105.

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