HIGH ACCURACY OMEGA TIMEKEEPING

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ABSTRACT

The Smithsonian Astrophysical Observatory (SAO) operates a worldwide satellite tracking network which uses a combination of OMEGA as a frequency reference, dual timing channels, and portable clock comparisons to maintain accurate epoch time. Propagational charts from the U.S. Coast Guard OMEGA monitor program minimize diurnal and seasonal effects. Daily phase value publications of the U.S. Naval Observatory provide corrections to the field collected timing data to produce an averaged time line comprised of straight line segments
called a time history file (station clock minus UTC). Depending upon clock location, reduced time data accuracies of between two and eight microseconds are typical.

INTRODUCTION

The purpose of this report is to provide a user's report on maintaining high quality time using OMEGA transmissions. This approach has evolved through the years taking accuracy, cost, reliability and quality of reference signals, and ease of time reduction into account. The equipment and timekeeping methods used to keep at least 6 microsecond reduced epoch time at two somewhat remote sites from the standpoint of precise time availability is the subject of this paper. The two sites are both located in South America, one at Natal, Brazil and the other at Arequipa, Peru.

SAO SATELLITE TRACKING NETWORK

Since 1957, the Smithsonian Astrophysical Observatory has operated a network of astrophysical observing stations to provide satellite observations in support of evolving scientific programs in geodesy, geophysics, celestial mechanics, the upper atmosphere, and earth and ocean dynamics. These came under NASA sponsorship in 1957. In geodesy and geophysics, the data acquired by the network of satellite tracking stations has been used to develop accurate mathematical models of the earth's size, shape, and gravity field.

THE OMEGA NAVIGATIONAL NETWORK

Maintained by the U.S. Coast Guard, a network of eight transmitting stations in the VLF frequency band provides location information to a certainty of 1 to 2 nautical miles with some correctional data. This OMEGA network provides near global coverage. All stations transmit five frequencies which are time sequenced during a ten second interval, each frequency being broadcast in a pattern for about one second each. In this way only one of the eight OMEGA transmitters operates on a particular frequency at a time. Using a time sequenced receiver, individual transmitter locations and frequencies may be selected for navigational or frequency reference use. Each OMEGA transmitter site is referenced to UTC and is maintained to UTC to better than 2 microseconds by portable clock trips and one-way phase measurements between OMEGA transmitter sites. Thus, OMEGA transmissions have proved to be quite valuable in maintaining a continuous frequency reference for a timekeeping system, especially where other time reference signals such as Loran-C and TV time techniques are unavailable.

THE TIMING SYSTEM

Fundamental to a satellite tracking operation where range and positional data is taken is time and frequency. All tracking stations have a timekeeping system to provide epoch time data for each satellite observation. Since these sites are usually many hours by car and airplane from a time and frequency laboratory, utmost precautions have been taken to maintain continuous epoch and frequency signals for the tracking site. To insure the site be self-sufficient for as long as possible, a dual timekeeping system was provided to guard against loss of epoch time due to signal interruptions or equipment malfunctions. In addition, a battery backup system capable of withstanding a power blackout of up to two days is included (in the event that even the electric generator is not operational). For instance, it is not unusual for local power to be interrupted in Peru at least twice per week.

Figures 1 and 2 show the make up the timing system. At the present time a satellite receiver and a Loran receiver are not in either South American sites. In the main timing channel a cesium frequency standard in used. In the other redundant channel a rubidium is sufficient. A high frequency receiver is included to verify epoch to the millisecond level. An OMEGA receiver in each timing channel selects a different OMEGA station, one which is also monitored by the U.S. Naval Observatory. Duplicate time accumulators are used in the main timing channel. Digital phase shifting circuitry permits timing epoch adjustments in 0.1 microsecond steps. Crystal oscillators are running in case of any timing channel oscillator failure. In adition, an OMEGA monitor receiver is used to provide data to the global OMEGA transmission model being generated by the US Coast Guard, as well as provide a backup for the other OMEGA receivers on site. This monitor is capable of receiving transmissions from eight transmitter sites at three different frequencies each.

TIMEKEEPING METHODS USING OMEGA

In order for OMEGA to be used for timekeeping, a clock trip to the site is necessary to initialize the timekeeping system and the OMEGA receiver. The OMEGA receiver must have all of its divider chains reset. A reference value of phase shift from the master clock set coincident to UTC must then be determined. A propagation correction chart calculated from a worldwide OMEGA transmission model for the tracking site is used to determine the GMT that has the least variation seasonally. The PPC chart, so called, is available from the U.S.Coast Guard and is shown in Figure 3 for Peru. Also a PPC chart is needed to check the seasonal variation of the OMEGA phase as received by USNO for the frequency and transmitter site used. Strong diurnal phase shifts occur during transition from night to day along the OMEGA transmission path from the transmitter to the receiving site. A GMT time for making OMEGA reading is best during the middle of an all night time or all daylight transmission path. Also a choice of an OMEGA station which is oriented so that the transmission path is in a

North-South orientation provides the longest reliable reading time. That is why the Peru site uses the OMEGA transmission from North Dakota and the Brazil site uses an Argentina transmission. Data from both timing channels is recorded twice per day during the selected best GMT times. Since the OMEGA transmitter site is maintained very closely to UTC(USNO), the propagation phase corrections as recorded by USNO are factored into calculating the final reduced epoch data usually about one month after the fact.

WHAT CAN GO WRONG

Timekeeping using OMEGA as a reference has proved to provide rather troublefree service for periods of about two months. Problems can results from the following occurences:

- Clock jumps or malfunctions at the tracking site
- Cycle jump due to a low signal or storm
- Drift in the main channel oscillator
- Drift or step in the OMEGA transmitter relative to UTC
- Station off air

Most of these circumstances may be dealt with without any loss in timekeeping uncertainty, especially where the servo controlled OMEGA receiver may be slewed or reset to previous setup reference values.

RESULTS OF THE BRAZIL AND PERU TIMEKEEPING SYSTEMS

See figures 4 and 5 for the received phase values for Brazil and Peru.

Data for the past year from May, 1980 to May, 1981 is provided in table 1.

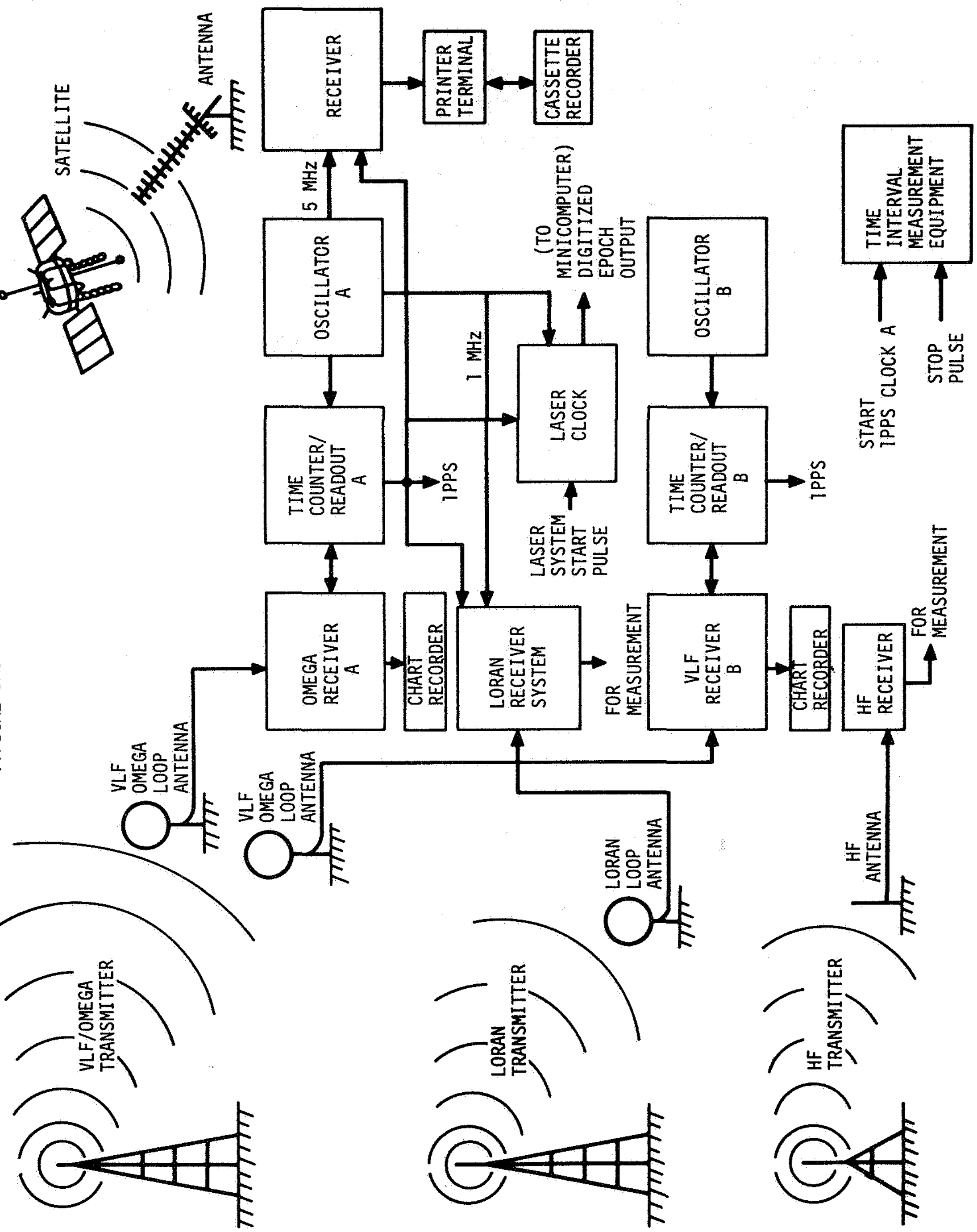
All data is long term averaged and straight line segments are assumed to produce a time line relative to UTC.

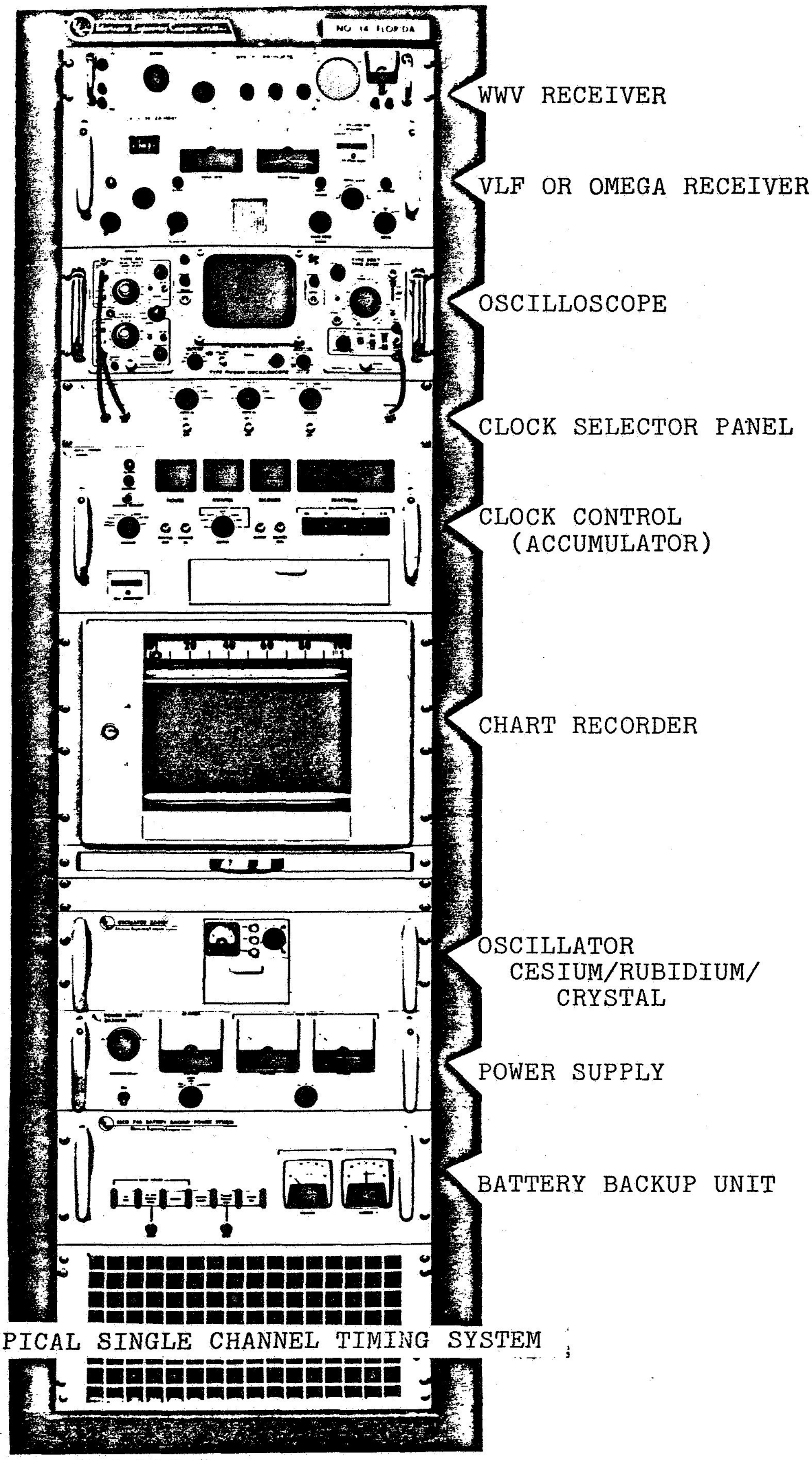
CONCLUSIONS

OMEGA as a timekeeping reference has proved to be very reliable and accurate to 2 to 8 microseconds for the SAO sites in South America. When the timing uncertainty becomes greater than 6 microseconds, a clock trip would be planned other than the yearly clock check. However, this has rarely been necesary for maintaining time to the five microsecond level.

It is anticipated that the range tracking accuracy will improve threefold next year due to improvements in laser pulse width and higher pulse repetition rate. Then a greater timing accuracy will be required, perhaps better than what OMEGA can provide. Then for the short term more clock trips will be necessary and the clock trip fuse perhaps set for an uncertainty of 4 microseconds will have to be adopted until an alternative improved timing reference is adopted. GPS, high accuracy spread spectrum Nova/Transit, or a devoted satellite such as proposed by Dr. Vessot of SAO (orbiting maser) are possibilites to make this improvement. (I would like to thank the US Coast Guard ONSOD branch for their assistance.)

Figure 1
TYPICAL SAO TIMEKEEPING SYSTEM





TYPICAL SINGLE CHANNEL TIMING SYSTEM

FIGURE 2.

FIGURE 3.

13.6 KHZ OMEGA PROPAGATION CORRECTIONS IN UNITS OF CECS

PERU (LIBERIA OMEGA)

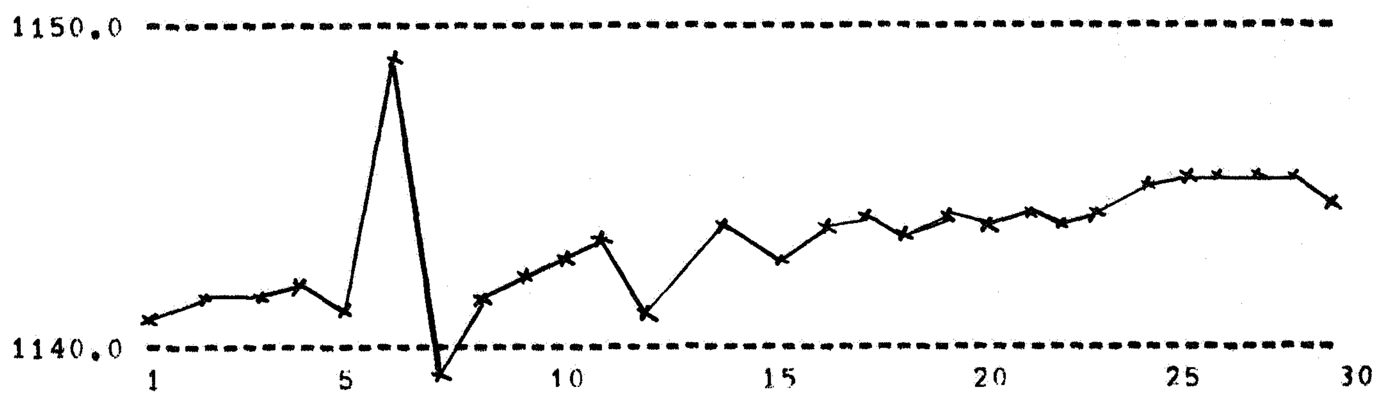
DATE		GMT 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1-15	JAN	259	262	264	265	265	265	265	251	204	158	118	118	116	111	108	107
16-31	JAN	259	262	264	265	265	265	265	254	209	164	121	117	116	112	108	107
1-14	FEB	259	262	264	265	265	265	265	255	212	169	125	116	116	111	108	106
15-29	FEB	259	263	264	265	265	265	265	255	212	172	128	115	116	111	107	106
1-15	MAR	260	263	264	265	265	265	265	252	212	172	130	114	115	111	107	106
16-31	MAR	260	263	264	265	265	265	265	249	210	172	132	113	115	111	107	106
1-15	APR	261	264	265	265	265	265	265	245	208	172	133	113	115	111	108	107
16-30	APR	262	264	265	265	265	265	265	243	207	172	134	113	115	112	109	108
1-15	MAY	262	264	265	265	265	265	265	241	207	173	136	113	116	112	110	109
16-31	MAY	262	264	265	265	265	265	265	241	207	175	138	114	116	113	110	110
1-15	JUN	262	264	265	265	265	265	265	242	209	177	141	114	116	114	111	110
16-30	JUN	262	264	265	265	265	265	265	243	211	179	143	115	116	114	111	110
1-15	JUL	262	264	265	265	265	265	265	245	212	180	145	115	116	114	111	110
16-31	JUL	261	264	265	265	265	265	265	246	213	180	144	115	116	114	111	110
1-15	AUG	261	264	265	265	265	265	265	246	212	178	141	113	116	113	110	109
16-31	AUG	261	264	265	265	265	265	265	245	210	175	136	113	115	112	109	108
1-15	SEP	261	264	265	265	265	265	265	243	206	169	129	114	115	111	108	107
16-30	SEP	261	264	265	265	265	265	265	240	202	163	123	115	114	110	107	106
1-15	OCT	261	264	265	265	265	265	265	237	196	156	117	116	114	109	106	106
16-31	OCT	261	264	265	265	265	265	265	235	192	150	115	117	114	109	107	106
1-15	NOV	261	263	264	265	265	265	265	235	190	146	114	117	114	109	107	107
16-30	NOV	260	263	264	265	265	265	265	236	190	145	115	118	114	110	107	107
1-15	DEC	260	263	264	265	265	265	265	241	193	147	115	118	115	111	108	107
16-31	DEC	259	263	264	265	265	265	265	246	198	151	116	118	116	111	108	107

ALL NIGHT PATH

ALL DAY

FIGURE 4. TIME DRIFT REPORT September, 1981

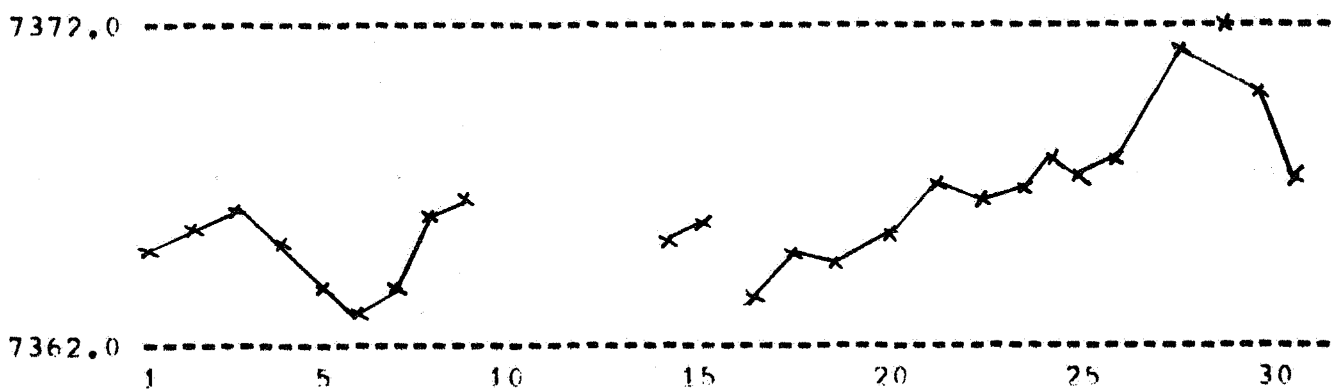
Natal, Brazil
SAO Tracking Site



September 1981 1500Z
Vertical Axis is in Microseconds

FIGURE 5. TIME DRIFT REPORT September, 1981

Arequipa, Peru
SAC Tracking Site



September, 1981 0600Z
Vertical Axis is in microseconds

TABLE I. SAG NETWORK TIMEKEEPING STATUS

for July 1980 thru May 1981

STATION	REDUCTION PERIOD		STAT - UTC	REDUCTION UNCERTAINTY
BRAZIL	JUL 1	DEC 31,80	-4 TO 16	3 TO 5
	JAN 1	FEB 9, 81	13 TO 19	3
	FEB 9	MAY 1, 81	-6 TO 0	3
	EXCEPT JULY 15		3 TO 16	22
	JULY 22		-64628	64630
PERU	JUL 1	DEC 31,80	-9 TO 19	2 TO 3
	JAN 1	JAN 17,81	19 TO 24	4
	JAN 17	MAY 1, 81	-8 TO -2	4 TO 5