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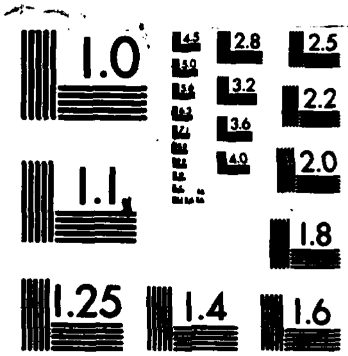
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Specification of the Transmitted Signal of the Omega Navigation System

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January 1984
Final Report

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NOTICE

NOTICE

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16. Abstract

This report documents the specification of the transmitted signal of the OMEGA Navigation System. It is intended as a reference document consisting of specifications, definitions, and explanations for general use by designers, manufacturers, and users of this system.

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PREFACE

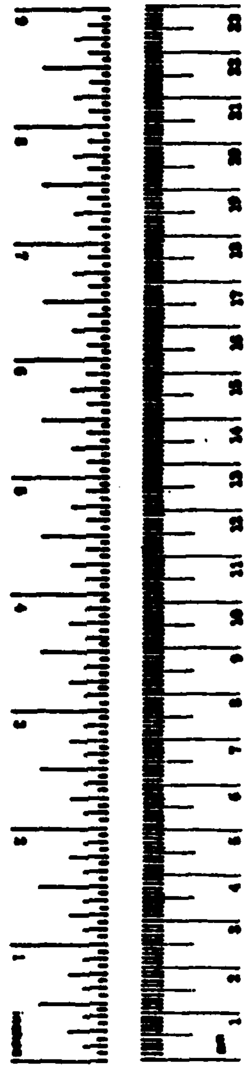
In July 1981, a set of signal specifications was published for the LORAN-C radionavigation system. The development of these specifications was restricted to the characteristics of the LORAN-C signal at the transmitter; however certain characteristics of the overall system were considered. The experience gained in the development of the LORAN-C signal specifications identified the need for a similar set of specifications for the OMEGA Navigation System. Those specifications are reported herein.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

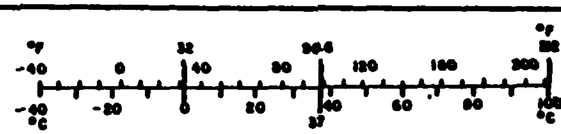
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

OMEGA is a very low frequency, phase comparison (hyperbolic or rho-rho) radionavigation system operating in the 9-14 kHz VLF band. A network of eight transmitting stations is used to provide worldwide, all-weather position fixes of moderate accuracy (2-4 NM).

After initial development by the U.S. Navy, responsibility for OMEGA system operations shifted to the U.S. Coast Guard in its role as a provider of radio aids to marine navigation. Additional sponsorship of OMEGA operations has come from the participating host nations - Argentina, Australia, France, Japan, Liberia, and Norway.

The practicality of the OMEGA system is related to the stability and predictability of the phase of a VLF signal over a very long path. The actual OMEGA position-fixing process involves comparison of phase values obtained from several transmitting station signals. This specification defines the characteristics of these signals at the transmitters.

1.1 PURPOSE

This specification provides a technical description of the OMEGA system signal produced at the transmitting stations. It is intended as a reference document consisting of specifications, definitions, and explanations for general distribution to designers, manufacturers, and users of this system.

1.2 SCOPE

This specification is restricted to the operational transmitted signal; however, other aspects of the system are discussed for information purposes. Section 2 provides general background information on the OMEGA system. The transmitted signal specification is presented in Section 3. Factors relevant to system usage are discussed in Section 4 and definitions of terms are given in Section 5.

2. OMEGA SYSTEM OVERVIEW

Basic descriptions and explanations of the OMEGA system and its elements and characteristics are presented here as introductory material prior to the definition of the transmitted signal specification itself. That specification is defined in Section 3. The material in this section has been taken primarily from the Federal Radionavigation Plan, 1982 Edition (ref. 1) and OMEGA Global Radio Navigation - A Guide for Users (ref. 2).

2.1 CONFIGURATION

The OMEGA system is operated by the US Coast Guard in partnership with six other nations. The OMEGA transmitting system configuration is shown in Figure 1. Site designations, locations, antenna types and cognizant operating agencies are summarized in Table 1. The system has operated for several years with a seven site configuration. The eighth site, Australia, became operational in August of 1982.

Although different types of antennas are used at the various sites, the complement of electronic equipment is virtually the same at all sites and consists of the following subsystems:

AN/FRN-30, Timing and Control Set
AN/FRT-88, Radio Transmitter Set
AN/FRQ-18, Antenna Tuning Set

The timing and control and transmitter equipment is located in a building remote from the antenna. The antenna tuning equipment is located in a separate building at the base of the antenna.

2.2 SIGNAL CHARACTERISTICS

OMEGA transmitting stations generate continuous wave (CW) signals referenced to Coordinated Universal Time (UTC) on four navigation frequencies: 10.2 kHz, 11.05 kHz, 11.33 kHz and 13.6 kHz. In addition to these common frequencies, each station transmits a unique frequency which aids in station identification and, in some cases receiver synchronization. Each frequency is transmitted essentially as a 10 KW segment for a nominal one second period with 0.2 seconds of silence between frequencies. Individual patterns of eight segments are transmitted by each station over a 10 second period. These patterns are repeated every 10 seconds. Site specific characteristics will be established in Section 3.

2.3 ACCURACY

The inherent positioning accuracy of the OMEGA system is limited by the accuracy of the propagation corrections that must be applied to the individual receiver readings.* The corrections may be obtained in the form

*Propagation corrections account for ground conductivity, magnetic field effects, and daily and seasonal variations, but less than perfect knowledge of these factors limits the accuracy of the propagation corrections.

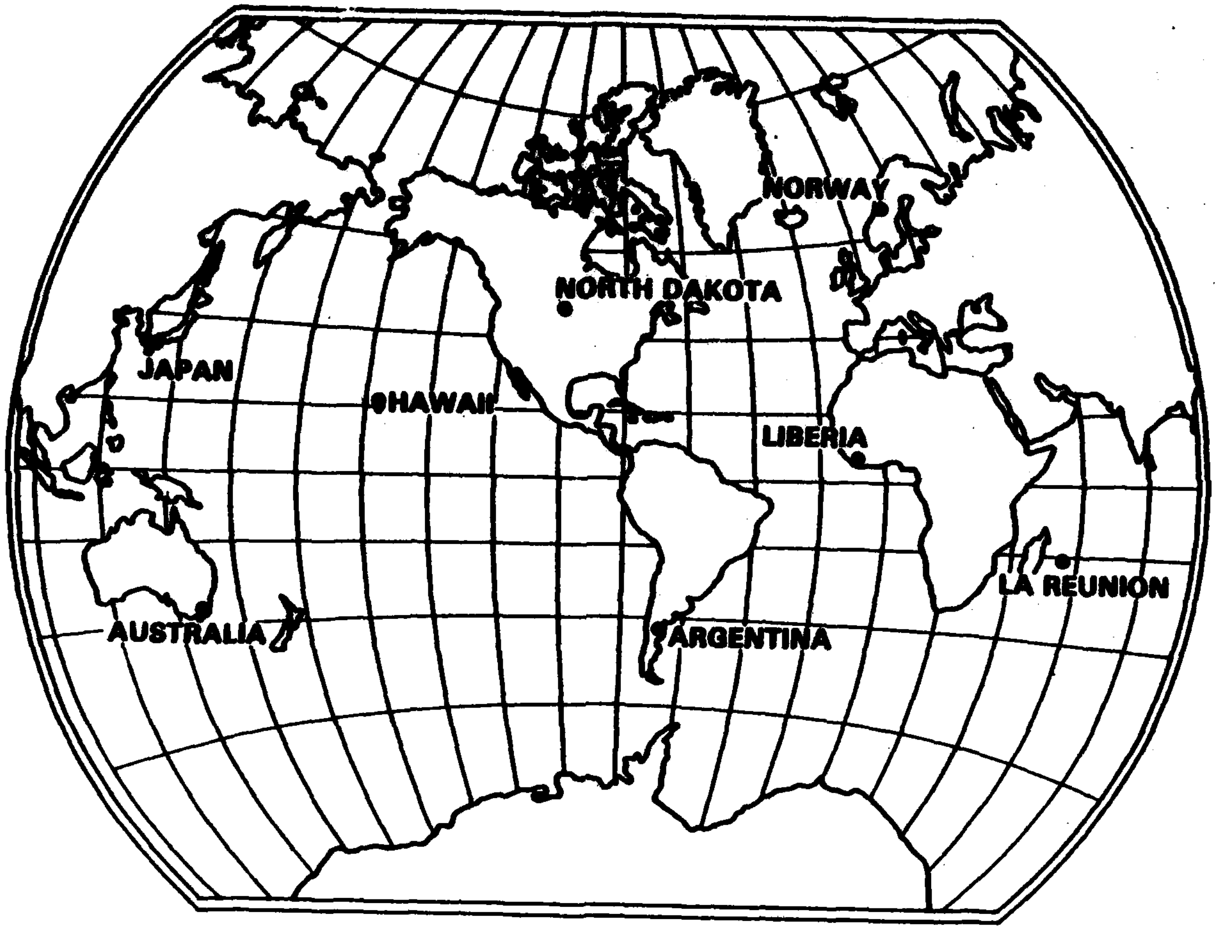

FIGURE 1. EIGHT STATIONS PROVIDING ALL WEATHER WORLDWIDE VLF RADIONAVIGATION

TABLE 1. OMEGA STATIONS

Station	Letter Designation	Coordinates*	Operator
NORWAY	A	66 25 12.62 N 13 08 12.52 E	Norwegian Telecommunication Administration (NTA)
LIBERIA	B	6 18 19.11 N 10 39 52.40 W	Liberian Ministry of Commerce, Industry and Transportation
USA: Oahu, Hawaii	C	21 24 16.78 N 157 49 51.51 W	U.S.C.G.
USA: La Moure, N. Dakota	D	46 21 57.29 N 98 20 08.77 W	U.S.C.G
FRANCE: La Reunion	E	20 58 27.03 S 55 17 23.07 E	French Navy
ARGENTINA	F	43 03 12.89 S 65 11 27.36 W	Argentine Navy
AUSTRALIA	G	38 28 52.53 S 146 56 06.51 E	Australian Department of Transport
JAPAN	H	34 36 52.93 N 129 27 12.57 E	Japanese Maritime Safety Agency (JMSA)

*World Geodetic System 1972 (WGS-72)

of predictions from tables or automatically in computerized receivers. The system has a design goal of a predictable accuracy of 4 nm (2 drms). Area of validations conducted to date indicate this goal is being met. Achievable accuracy depends on location, station pairs used, time of day, and validity of the propagation corrections.

Propagation correction tables are based on theory and modified to fit monitor data taken over long periods for localized areas. An extensive monitoring program is in use to verify the propagation model used to predict the corrections and the system accuracy in the area of the monitor stations. The specific accuracy and coverage depends on the type of equipment used, level of operator training, time of day, and related factors. In many cases, accuracies of 2 nm (2 drms) day and 4 nm (2 drms) night are being achieved or exceeded. Although the system is usable, a continuing program of monitoring and validating OMEGA signals presently exists. This validation program helps define system capabilities and limitations. At this time about 60 percent of the OMEGA oceanic coverage area has been validated, with the remaining validations to be completed in 1983-1986.

2.4 AVAILABILITY

Exclusive of infrequent periods of scheduled off-air time for maintenance, OMEGA availability is greater than 99 percent per year for each station and 95 percent for any three stations. Annual system availability generally has been greater than 97 percent with scheduled off-air time included.

2.5 COVERAGE

The OMEGA system provides air and marine users with a continuous all-weather navigation information over 95 percent of the world.

2.6 FIX RATE

The OMEGA system provides independent, nearly continuous, positional fixes.

2.7 FIX DIMENSION

OMEGA will furnish two or more lines of position (LOPs) to provide a two-dimensional fix.

2.8 CAPACITY

An unlimited number of receivers may be used simultaneously.

2.9 AMBIGUITY

In this CW system, ambiguous LOPs occur as there are no means to identify particular points of constant phase difference which recur throughout the coverage area. The area between lines of zero phase difference are termed "lanes."* Multiple-frequency receivers extend the lane width, for the purpose of resolving lane ambiguity. Because of the lane ambiguity, receivers must be preset to a known location. Once set to a known location, the OMEGA receiver counts the number of lanes it crosses in the course of a voyage. This lane count is subject to errors which may be introduced by an interruption of power to the receiver, changes in propagation conditions near local sunset and sunrise and other factors. The accuracy of an OMEGA phase-difference measurement is independent of the elapsed time or distance since the last update. Unless the OMEGA position is verified occasionally by comparison to a fix obtained with another navigation system or by periodic comparison to a carefully maintained DR plot, the chance of an error in the OMEGA lane count increases with time and distance. These errors are eliminated in modern receivers since they can combine multiple frequencies to develop large lane widths which resolve ambiguity problems. Lane widths of approximately 288 miles along the base line can be generated with a receiver using all four navigation frequencies.

* The lane width of 10.2 kHz signals is about 8 nautical miles on the baseline between stations.

3. OMEGA TRANSMITTTED SIGNAL SPECIFICATION

The transmitted signal of the OMEGA radionavigation system is completely defined in terms of its frequency, format, time, power, and transmission mode characteristics. Such characteristics are specified on the following subparagraphs. (ref 1-9).

3.1 FREQUENCY

The OMEGA system shall transmit on frequencies in the very low frequency (VLF) band of 9-14 kHz which is internationally reserved for radionavigation.

3.1.1 Navigation Frequencies

Each OMEGA station shall transmit continuous wave (CW) navigation signals on four common frequencies (wavelengths), specifically:

Frequency (kHz)	Wavelength (m)*
10.2	29468.087
11.05	27201.265
11.33	26521.279
13.6	22101.066

3.1.2 Unique Frequencies

Each OMEGA station shall transmit an identifying signal unique to itself as specified below:

	Station	Frequency (kHz)	Wavelength (m)*
A)	Norway	12.1	24840.826
B)	Liberia	12.0	25047.833
C)	Hawaii	11.8	25472.372
D)	No. Dakota	13.1	22944.580
E)	La Reunion	12.3	24436.910
F)	Argentina	12.9	23300.310
G)	Australia	13.0	23121.076
H)	Japan	12.8	23482.343

3.2 SIGNAL FORMAT

The frequencies specified in Section 3.1 shall be generated as continuous wave (CW) signals transmitted in accordance with the signal format specified in Figure 2. The OMEGA signal format specified in Figure 2 shall be repeated every 10 seconds without interruption.

*Speed of Light, $C=3.00574 \times 10^8$ m/s

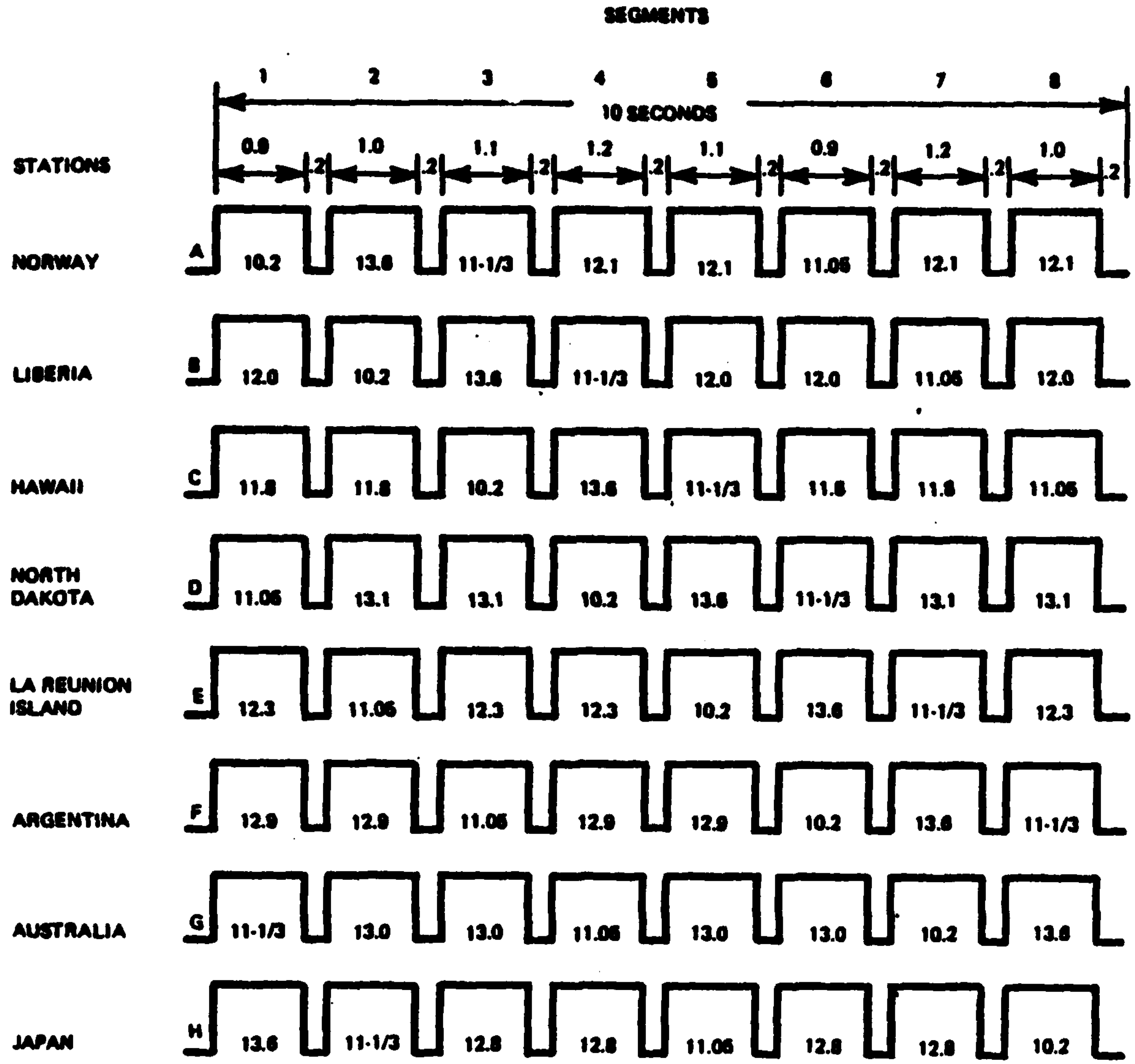

FIGURE 2. OMEGA RADIONAVIGATION SYSTEM SIGNAL TRANSMISSION FORMAT

3.3 TIME

The OMEGA frequencies shall be generated by cesium standards. Each station is synchronized to within ±2 microseconds of system time and system time is maintained to within 5 microseconds of Coordinated Universal Time (UTC).

3.3.1 Time Reference

The starting time of Segment 1 of the signal format specified in Section 3.2 shall be 0 hours, 0 minutes, and 0 seconds referred to 00:00:00 hours 1 January 1972. As of 00:00:00 hours 1 July 1983 the start time of Segment 1 will lead UTC by 12 seconds since UTC "leap second" corrections are not introduced to the OMEGA time reference.

3.3.2 Frequency Control

All frequencies and timing pulses shall have a common epoch (i.e., all carrier references, timing pulses and keying pulse sequences shall pass through zero in a positive direction at the same time, every thirty seconds, OMEGA time). The shortest such interval, or common coincidence of the four navigational frequencies shall be approximately 3.53 milliseconds. The common interval shall correspond to 36 cycles at 10.2 kHz frequency, 39 cycles at 11.05 kHz, 40 cycles at 11.333 kHz and 48 cycles at 13.6 kHz.

3.3.3 Phase Control

The radiated phase shall be controlled such that the maximum average phase error shall be less than one degree when averaged over one minute. For phasing purposes, it shall be considered that all carriers are continuous so that they may be compared at any time.

3.3.4 Transmission Periods

Transmission periods shall be held as specified in Section 3.2 within the following limits:

Keying-on Time - Time specified within 0 to +1 microsecond

Keying-off Time - Time specified within 0 to +5 microseconds

3.3.5 Rise Time

OMEGA pulses, nominally rectangular, are actually slowly rising due to transmitter antenna bandwidth. Pulse rise times to 63 percent amplitude shall be as specified in Table 2.

TABLE 2.

PULSE POWER AND RISE TIME CHARACTERISTICS

STATION	F	T	STATION	F	T
A) NORWAY	10.2	9	E) LA REUNION	10.2	13
	11.05	7.5		11.05	11
	11.33	7		11.33	9.5
	*12.1	5.7		*12.3	7.7
	13.6	4		13.6	6
B) LIBERIA	10.2	13	F) ARGENTINA	10.2	19.9
	11.05	10.5		11.05	16.5
	11.33	10		11.33	16
	*12.0	8.6		*12.9	12.9
	13.6	6		13.6	10.5
C) HAWAII	10.2	12	G) AUSTRALIA	10.2	15
	11.05	10		11.05	13
	11.33	9.5		11.33	12.5
	*11.8	8.6		*13.0	10
	13.6	6		13.6	8
D) NO. DAKOTA	10.2	23	H) JAPAN	10.2	12
	11.05	22		11.05	10
	11.33	19.5		11.33	9.5
	*13.1	15.1		*12.8	8.5
	13.6	12.5		13.6	6

*designates unique frequencies

F = Frequency in kHz

T = Rise Time to 63% amplitude in milliseconds

3.4 POWER

The maximum power output of the OMEGA Transmitter Set (AN/FRT-88) is 150 kilowatts (KW). The actual transmitter power is set to radiate 10 KW on all frequencies at all stations.

3.5 PROPAGATION MODE

OMEGA signals in the earth-ionosphere waveguide can be considered (mode picture) as the sum of infinitely many quasi-TM (Transverse Magnetic) and quasi-TE (Transverse Electric) modes. Because the calculated propagation corrections (Section 2.3) are based on first TM mode models, the only useful signals are those propagated in the first TM mode. The "Mode 1 TM mode" is unambiguously defined except on certain path bearings near the equator.

4. USER INFORMATION

Information as to the operational status and use of the OMEGA navigation system is provided to the user community in several forms and by several agencies. These are reviewed in the following sub-sections. Further information can be obtained from the identified agencies.

4.1 U.S. COAST GUARD

The U.S. Coast Guard's OMEGA Navigation System Operations Detail (ONSOD) maintains a telephone answering device, (202) 245-0298, in Washington, DC which contains a recorded OMEGA status announcement. This announcement is updated as system changes occur. If additional information is required, ONSOD may be contacted at (202) 245-0837. ONSOD also originates OMEGA status change messages for distribution to selected government agencies.

4.2 DEFENSE MAPPING AGENCY HYDROGRAPHIC/TOPOGRAPHIC CENTER (DMAHTC)

The DMAHTC is one of the recipients of ONSOD status change messages. DMAHTC is responsible for providing official notification of status changes for all U.S. navigation systems to both public and private marine users. This notification is in the form of a radio navigational warning issued as a HYDROLANT/HYDROPAC message and/or as a NAVAREA IV/XII message.

HYDROLANT warnings are issued from the Naval communications stations listed below at the indicated times and frequencies:

Station	Time	Frequency
Norfolk, VA	0800-0900	8090, 12135, 16180 kHz
	1700-1800	8090, 12135, 16180, 20225 kHz
Key West, FL	0800-0900	5870 kHz
	1700-1800	5870, 25590 kHz
Thurso, Scotland	0800-0900	7504.5, 12691 kHz
	1700-1800	7504.5, 12691 kHz
Rota, Spain	0800	5917.5, 7705 kHz
	1500	5917.5, 7705 kHz
	1700	5917.5, 7705 kHz
	2200	5917.5, 7705 kHz
Nea Makri, Greece	0800-0900	4623, 13372.5 kHz
	1700-1800	4623, 13372.5 kHz

NAVAREA IV warnings are transmitted from Naval communication stations at:

Norfolk, VA	1500-1600	8090, 12135, 16180, 20225 kHz
	2200-2300	8090, 12135, 16180, 20225 kHz

Station	Time	Frequency
Key West, FL	1500-1600	5870, 25590 kHz
	2200-2300	5870, 25590 kHz

HYDROPAC warnings are transmitted from Naval communication stations at:

Guam	0100-0200	4955, 8150, 13380, 21760 kHz
	0800-0900	4955, 8150, 13380, 21760 kHz
San Miguel	0100-0200	8506, 10440.5, 122000 kHz
Phillipines	0800-0900	8506, 10440.5, 122000 kHz

NAVAREA XII warnings are transmitted from the Coast Guard Communications Station at:

Honolulu, HI	0300	4525, 9050, 13655, 16457.5, 22472 kHz
	1700	4525, 9050, 13655, 16457.5, 22472 kHz

For additional information, DMAHTC Publications 117A and 117B should be consulted.

4.3 NATIONAL BUREAU OF STANDARDS (NBS)

At 16 minutes past each hour, the National Bureau of Standards Station WWV (Fort Collins, Colorado) broadcasts a message concerning the status of each OMEGA station, signal anomalies, and other information concerning OMEGA. At 47 minutes past each hour WWVH (Hawaii) broadcasts similar information. These broadcasts are on 2.5, 5.0, 10, 15 and 20 MHz frequencies.

4.4 NOTICE TO AIRMEN

Time-critical aeronautical information which is of either a temporary nature or is not known sufficiently in advance to permit publication on aeronautical charts or in other operational publications, receives immediate dissemination via the National Notice to Airmen (NOTAM) Service, a telecommunications system. NOTAM information is distributed automatically by the National Communications Center to predetermined address listings of both local and distant air traffic facilities. All facilities do have immediate access, upon request, to all NOTAM information on file in the National Communication computer data base via the Notice to Airmen telecommunication system.

An integral part of the NOTAM System is the biweekly Notice to Airman (class II) publication. Class II refers to the fact that the NOTAMs appear in printed form for mail distribution as opposed to class I NOTAMs which are distributed via telecommunications.

The National Flight Data Center will issue an FDC NOTAM text upon receipt from ONSOD of information on all OMEGA navigation outages.

For further information the Airman's Information Manual or the United States of America Aeronautical Information Publication (AIP) should be consulted.

4.5 NOTICE TO MARINERS

The Notice to Mariners is published to advise mariners of important matters affecting navigational safety. Information for the Notice to Mariners is contributed by the following agencies: DMAHTC (Department of Defense) for waters outside the territorial limits of the United States; National Ocean Survey (Department of Commerce) for surveys and charting of the coasts and harbors of the United States and its territories; the U.S. Coast Guard (Department of Transportation) for the safety of life at sea and the establishment and operation of aids to navigation; and the U.S. Army Corps of Engineers (Department of Defense) for the improvement of rivers and harbors of the United States.

In addition to the regular issued notices on unplanned OMEGA station off-air periods, major planned maintenance normally takes place in the months listed for each station:

February	- Liberia
March	- Argentina
June	- La Reunion
July	- North Dakota
August	- Norway
September	- Hawaii
October	- Japan
November	- Australia

The actual off-air times are disseminated to users 4 to 6 weeks in advance of the actual off-air. The off-air may vary in length from a few days to several weeks, depending on the extent of maintenance or repairs required. Every effort is made to keep off-air time to a minimum.

4.6 OMEGA CHARTS

The principal U.S. organization responsible for producing and distributing OMEGA navigational charts and tables is the DMAHTC, located in Brookmont, Maryland. This government agency is tasked with producing navigational products for areas outside of U.S. domestic waters, for both military and civil use. The National Ocean Survey (NOS), National Oceanic and Atmospheric Agency in Rockville, Maryland, is tasked with providing charts for civil use, but only within U.S. domestic waters. The following is a summary of actual or planned production by these agencies.

4.6.1 DMAHTC

OMEGA Plotting Charts - DMAHTC has completed 114 charts in the 76-7700 Series. In addition, charts covering the polar regions are planned for production. These are small scale charts at approximately 1:2,188,000 scale.

International Hydrographic Organization (IHO) International Charts - DMAHTC has completed 31 in this series. The scale for the series is at 1:3,500,000.

Standard Nautical Charts - Many U.S. charts containing navigational and bathymetric information have had OMEGA lattice overlays added. Most of these are listed in DMAHTC Publication 1-N-L and are identified with a suffix (OMEGA). Their scales are 1:300,000 or smaller.

4.6.2 National Ocean Survey (NOS)

This agency began production of nautical charts (scale 1:300,000 and smaller) for U.S. coastal waters in 1980 with OMEGA lattice overlays.

4.7 OMEGA TABLES

Two basic series of OMEGA tables are available - propagation correction tables and lattice tables.

4.7.1 Propagation Correction Tables

The navigator using an OMEGA LOP receiver must apply a correction for the propagation delay from each station due to diurnal and seasonal changes. The navigator using this manual receiver must obtain these corrections from a series of tables. The only agency currently producing the correction tables is the DMAHTC.

For indexing purposes, the world has been divided into 26 areas. Originally, corrections were computed for the 10.2 kHz frequency and the 3.4 kHz difference frequency.* The 3.4 kHz corrections have been discontinued and 13.6 kHz corrections substituted. The DMAHTC is producing correction tables in which those corrections in areas of predicted severe modal interference are shaded gray as means of warning the navigators that such OMEGA stations may give unreliable fixes if used during the times the values are shaded.

4.7.2 Lattice Tables

The lattice tables, also published by DMAHTC, allow the navigator to plot lines of position on standard nautical charts (scales smaller than 1:300,000) within an OMEGA lattice overprint. Selected station pairs, based on best crossing angle and gradient are computed for each table area. There are currently 261 lattice tables in the distribution system. An average of six pairs are available for each table.

*Heterodyning 10.2 kHz and 13.6 kHz.

5. DEFINITIONS

This section contains general definitions of terms used throughout this specification.

Aid to Navigation - A device or system external to a vehicle intended to help operators determine their position or warn them of danger.

Ambiguity - In the OMEGA system ambiguous lines of position occur as there is no means to identify particular points of constant phase difference which recur throughout the coverage area. Because of this ambiguity receivers must be pre-set to a known location.

Availability - The measure of the time an aid to navigation is able to provide a usable signal in the advertised coverage area of the system.

Drms - The Distance Root Mean Squared is a measure of error. It assumes that the statistical distribution of errors is normal (gaussian). On this basis, an error expressed as (drms) refers to the probability that a circle (or a circle equivalent to an ellipse) of radius shown will contain 63.2 percent of all data points. Two-drms is 2 times drms, and refers to the circle containing 95 percent of the probable readings.

Fix - A relatively accurate measure at a given time, determined without reference to any former position, and obtained by establishing the location of a vehicle with respect to one or more external reference points.

Leap Second - Coordinated Universal Time (UTC), an atomic time scale, is adjusted one second from time to time to restore it to Universal Time (UT) which tracks the earth's rotation on its axis.

Nautical Mile (NM) - 1852 US standard meters (meters defined by Department of Commerce as standard).

Navigation - The art or science of directing the movements of a vehicle from one place to another.

Navigation System - A system capable of being used to navigate. It includes the receiving equipment, its operators, the rules and procedures governing their actions and, to some extent, the environment which affects the vehicle.

Position Accuracy - This is a measure of the error between the point desired and the point achieved, or between the position indicated by measurement and the true position. Accurate determination of position is dependent upon the capability of the navigation system to provide precise information, the user's ability to interpret this information, correct geodetic coordinates, and proper cartography (when required). There are many ways of expressing position accuracy. In general, the error is statistical in character and can only be expressed in terms of a distance that will not be exceeded in some percentage of cases.

System Accuracy - is the expected accuracy of the system expressed in drms units, not including errors which may be introduced by the user, or geodetic or cartographic errors.

Predictable Accuracy - is the accuracy of predicting position with respect to precise space and surface coordinates.

Relative Accuracy - is the accuracy with which a user can measure current position relative to that of another user of the same navigation system at the same time.

Repeatable Accuracy - is the accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.

Radiodetermination - The determination of position, or the obtaining of information relating to position, by means of the propagation properties of radio waves.

Radionavigation - Radiodetermination used for the purposes of navigation, including obstruction warning.

Rise Time - The time required for a signal pulse to rise to 63 percent of its final amplitude.

2-drms - (See Drms)

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