MICROWAVE, OPTICS, LASERS, AND OTHER EXOTIC SYSTEMS

by Robert Stone*

It is good to work in a real world if possible, and the real world in time and frequency has had a look over the years as shown in Figure 1. NRL has been active in this field since the early 1920's. The solid curve represents what the real need has been over the years in precision time and frequency, and the dotted curve represents the state-of-the-art. In the beginning years of electronics, time and frequency were thought of separately. Tuning forks, crystals, etc. were used to control frequency; pendulums and other similar devices were used to control time. For the greater part of the time, the state-of-the-art in time and frequency has been a factor of 10 greater in accuracy than was actually needed. Communication during this period was very simple and the time/frequency problems could be very easily met.

A major breakthrough in time/frequency techniques occurred with the advent of the ring crystal in 1930. By 1940, standards capable of maintaining frequency to 10^8 and time to 1 msc were available. During this period, operational requirements for precision time and frequency were also increasing. Navigation systems, such as LORAN, were coming into being and digital communication systems required in teletype systems were being introduced. In the 1940's, a number of 0 temperature coefficient crystals were being developed, such as the GT cut crystal in 1942 and the AG cut in 1950.

About 1960, frequency synthesizers were developed which allowed a much more precise control of transmission frequencies. Concurrent with

*Head, Radio Time and Frequency Section, Naval Research Laboratory, Washington, D.C. (202) 767-3454.

TIMING - NEED VERSUS TECHNOLOGY

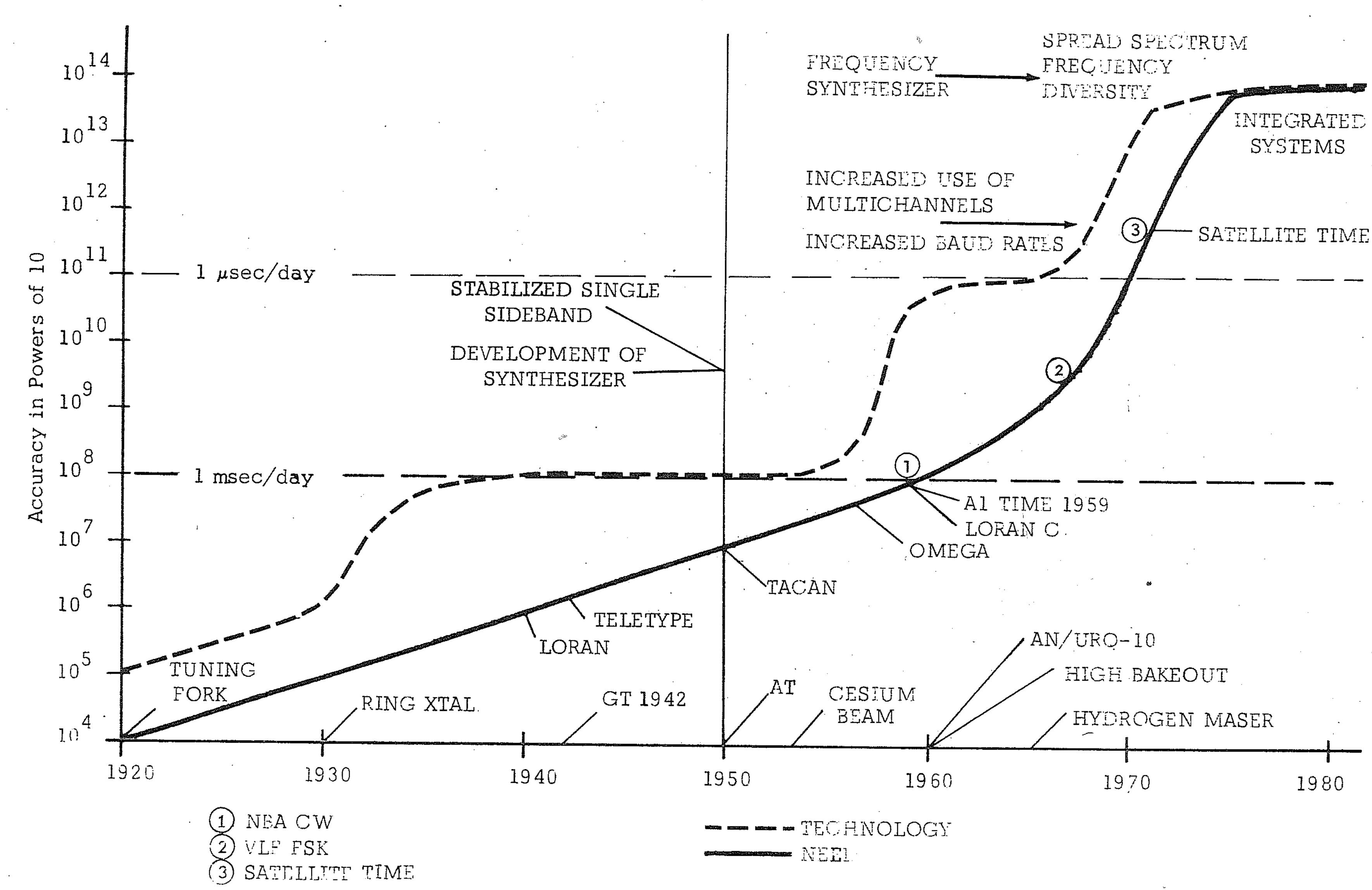


FIGURE 1

this was the development of stabilized single-side band systems. Prior to this point in history, the techniques which were used were simple and easily understood. Operation and maintenance were performed through intuition. All that was needed of precision time and frequency was sufficient frequency control to hold the signal within the band passes of the system employed.

About 1950, things began to change. More and more precision was being required in frequency and time. The intuitive approach to electronic operation and maintenance began to give way to a greater use of instrumentation. As more systems were developed (such as TACAN, OMEGA, LORAN-C in the navigation area; and use increased of the teletype, stabilized single-side band, higher baud rates, and the use of multichannel operation in the communications area), the demand for more precision in time and frequency increased. Figure 1 shows an increase of about an order of 10 in precision for each decade up to about 1950. Somewhere between the 1950's and 1960's, there was an upswing, until in the decade between 1960 and 1970 there was an increase of about three orders in the operational need of precision time and frequency. This need is still increasing. With the advent of satellite communication, spread spectrum frequency diversity, and integrated systems, it can be expected that eventually a time will come in which all the precision time and frequency which can be provided by the state-of-the-art will be utilized in operational systems. If the present rate of increase continues, this point may be reached at some time in the next decade.

The aim of the time and frequency program at NRL is to provide a practical path by which users of precision time and frequency can refer to a common worldwide standard at the Naval Observatory. A hierarchy is envisioned, such as is shown in Figure 2, in which the standards are maintained at the Naval Observatory; a long-range means of transfer is provided to various parts of the world; then, branching from these points,

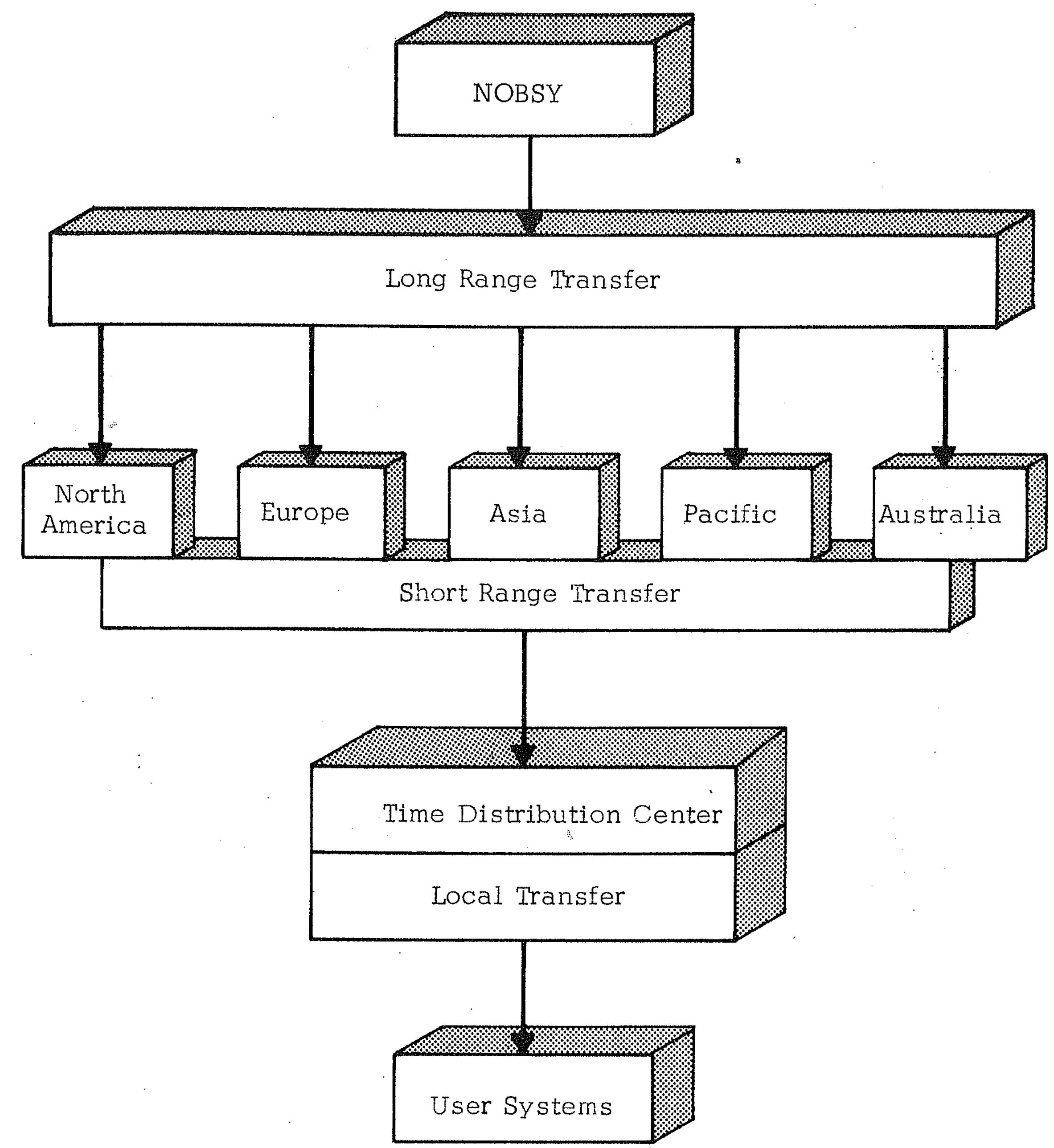

NOBSY
Long Range Transfer
North America
Europe
Asia
Pacific
Australia
Short Range Transfer
Time Distribution Center
Local Transfer
User Systems

FIGURE 2

there is a short range means of transfer to local time distribution centers which serve the user systems. This concept is shown another way in Figure 3. Any system which utilizes precision time or time interval also has a capability for the dissemination of time and time interval to the accuracy required in the system. The most economical way to transfer or disseminate time and frequency is to utilize those systems which require it. Such a system for long range transfer of time is the DSCS satellite system. Utilization of this system on a non-interfering basis will permit the transfer of precision time to about 1/10 msec anywhere in the world, which has the proper facilities. Following the same concept, short range and distribution of time and frequency would utilize available communication and navigation systems.

At present, the worldwide dissemination of precision time, as envisioned by NRL, appears as shown on Figure 4. Time will be introduced into the DSCS satellite system via a microwave link from the Naval Observatory. This link at present goes from the Observatory to NRL and Waldorf, but when the system becomes operational the link will go from the Naval Observatory to Brandywine, Maryland. Once in the DSCS satellite system, the transfer of time can be accomplished to virtually all major areas of the world. From these points, it is expected that other systems, such as LORAN-C, OMEGA, VLF, HF, etc., will be synchronized. Plans are being made to extend this hierarchy to the shipyard, the calibration center, and to ship and shore stations. One of the major problems in developing this hierarchy is to determine the users who should receive precision time and to set a system of priorities.

Short range transfer of time will be accomplished by cable, optical link, or microwave link. It is expected that the most extensive method will be the microwave link. Such a link has been established between the Naval Observatory and NRL. Figure 5 shows the characteristics of this link. The hydrogen masers at NRL can quite effectively be compared

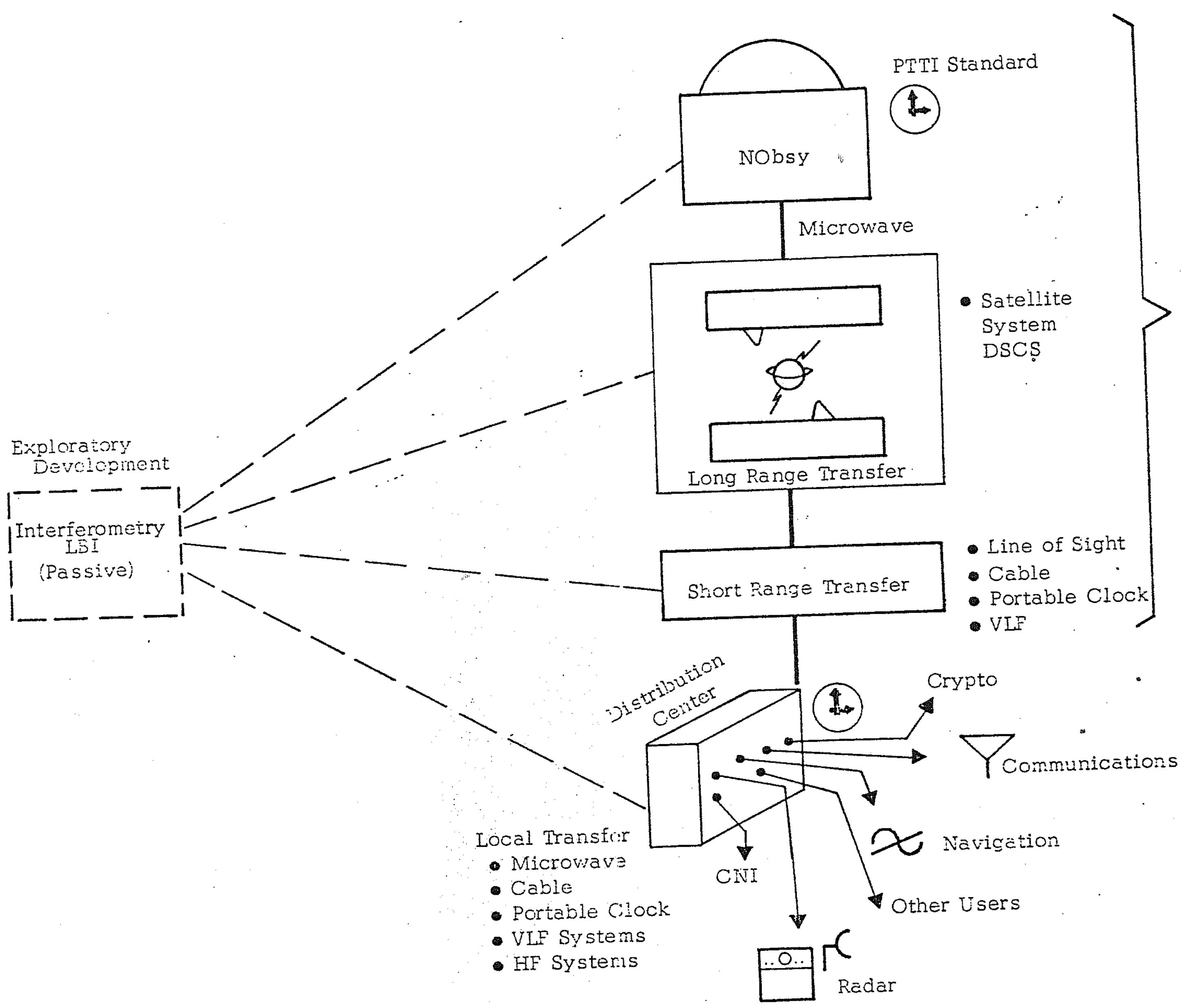

PTTI Standard
NObsy
Microwave
Satellite System DSCS
Long Range Transfer
Major Time Dissemina-tion System
Short Range Transfer
Line of Sight
Cable
Portable Clock
VLF
Exploratory Development
Interferometry LBI (Passive)
Distribution Center
Crypto
Communications
Navigation
Other Users
CNI
Radar
Local Transfer
Microwave
Cable
Portable Clock
VLF Systems
HF Systems

FIGURE 3

FREQUENCY TIME/TRANSFER

1 x 10/11 .1 microsec.

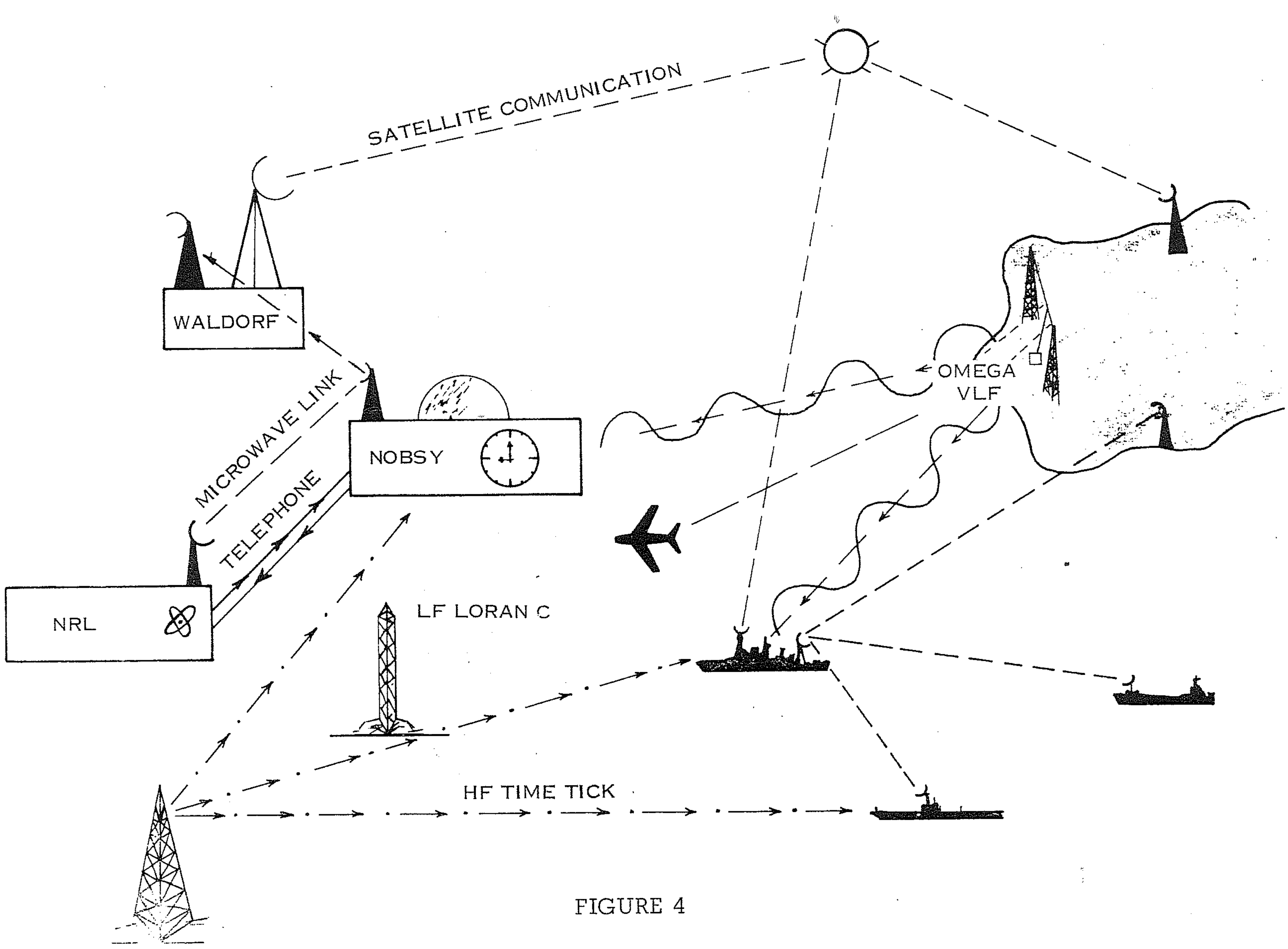
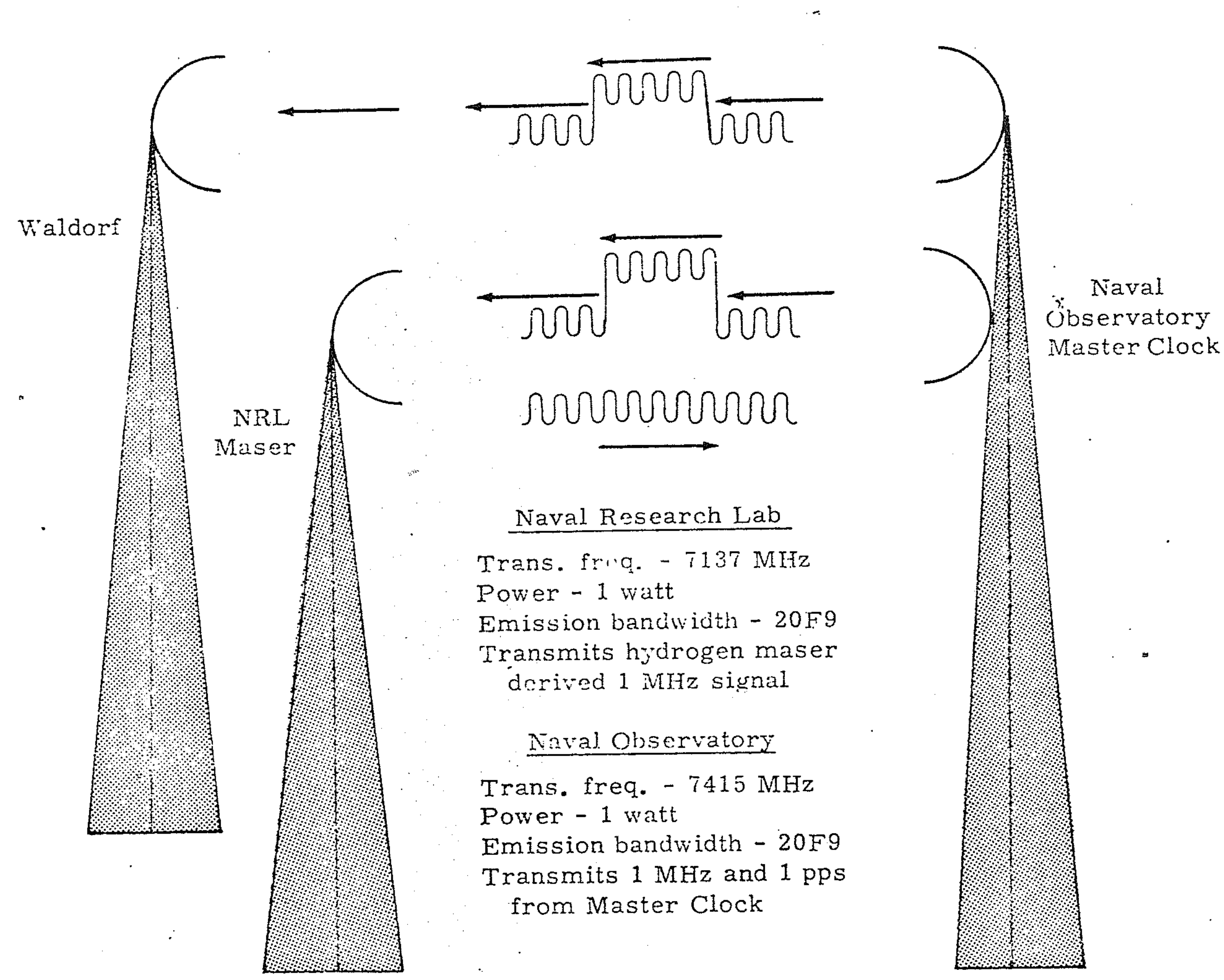


FIGURE 4

MICROWAVE LINK



Equipment: Raytheon Television Microwave Relay Model KTR-1000G

FIGURE 5

with the standards at the Naval Observatory via this link. Both a time tick and a 1-mc signal are transmitted. Accuracies of 10 msecs can easily be obtained. Although this link is devoted exclusively to the use of time frequency transfer, it is expected that comparable results will be obtained when the time transfer techniques are added to operational systems.

At present, NRL is investigating various operational systems which can be utilized for the short range transfer of time and it plans to develop techniques to extend the time hierarchy through these systems to the various DOD users.