THE GLOBAL RESCUE ALARM NET (GRAN) EXPERIMENT

James C. Morakis
Goddard Space Flight Center

ABSTRACT

The OMEGA Position Location Experiment (OPLE) was performed in 1967 by the Goddard Space Flight Center in order to demonstrate a position location and data collection system. OMEGA navigation signals were received at a remote site and retransmitted via a synchronous satellite to a ground processing center where data collecting and position determination were performed. Recent technological advances have made it possible to develop an Advanced OPLE System towards a global search and rescue application. This application generated some new problem areas such as the OMEGA lane ambiguity, random access, location accuracy, real-time processing, and size and weight of the Search and Rescue Communications (SARCOM). This experiment will demonstrate the feasibility of instantaneous alarm and position location by using a relatively inexpensive, battery operated, three-pound package. This package can transmit the alarm and position through a synchronous satellite to a search and rescue station in less than three minutes, in an environment of 50,000 to 100,000 subscribers drawn from the maritime, aircraft, and recreational communities.

INTRODUCTION

The advanced OPLE (OMEGA Position Location Equipment) concept was chosen by NASA, the Navy, and the U.S. Coast Guard (USCG) as the best suited system for search and rescue application. From a number of systems that were considered, this concept was the only one that satisfied the requirements of continuous global coverage using already existing OMEGA navigation signals.* Furthermore, this system concept is already under development at NASA GSFC for this and other applications; thus, the adaption of this system for search and rescue results in further savings in development time and cost. The above rationale led to a proposal for a joint NASA, Navy, USCG Global Rescue Alarm Net (GRAN) experiment.

The four essential elements of these experiments are; (1) the OMEGA navigation signals, (2) mobile Search and Rescue Communicators (SARCOM), (3) the geosynchronous satellite, and (4) the central data acquisition and processing station.

*By 1974 all eight OMEGA stations are expected to be operational.

The very low frequency (VLF) OMEGA signals will be received by the SARCOM and retransmitted to the geosynchronous satellite at UHF along with identification data. Next they will be relayed to the central data acquisition and processing station.

There, the location of the SARCOM will be determined from the VLF data, and the name of the distressed party will be obtained from the ID data.

The following technological objectives have been selected:

1. Demonstrate a low cost search-and-rescue system
2. Reduce SARCOM size, weight, and cost
3. Resolve the ambiguity inherent in the OMEGA navigation system
4. Provide real-time position determination and identification readout
5. Improve position location accuracy
6. Increase subscriber capacity while maintaining good accuracy and low probability of self-interference

The first objective will be achieved at the time of the experiment. The second objective will be effected by utilizing a modificiation of the ATS/OPLE design for the SARCOM. Major changes will be conversion from a VHF to a UHF uplink frequency of 402 MHz and a reduction in size, weight, and prime power requirements while the ERP remains the same. The unit will not require an interrogation receiver since transmission will be initiated at the SARCOM. The circuitry will be miniaturized so that it can be hand held and provide approximately 30 minutes of operation, although not necessarily continuous.

Through studies initiated at NASA/GSFC, the feasibility of reducing the present data collection platform volume and weight to less than 1000 cm^3 and 5 pounds has been established. SARCOM specifications call for the following requirements:

Volume	1000 cm^3
Weight	1 kg
Output Power	5 watts max
Frequency	402 MHz
Bandwidth	2.5 kHz
Operation	3-minute broadcasts repeated at approximately 20-minute intervals
Data	Social Security number (36 bits) or other unique identifier

These specifications will require the use of miniaturization techniques. An effort is well underway to demonstrate this feasibility. The OPLE platform circuitry has been breadboarded utilizing recent developments in integrated and linear circuits of standard size and configurations. Partitioning of circuit functions is complete and large scale integrated circuits are being fabricated. The major building blocks will be the transmission sequence timer, frequency dividers to generate offset frequencies, ID data generator, and UHF driver and power amplifiers.

The position location ambiguity in the OMEGA system as now implemented results in a lane width of 72 nm which is clearly inadequate for search and rescue applications. The simplest technical solution requires that two additional OMEGA navigational tones be provided to the already existing three OMEGA transmission format; this situation will result in a more complex and therefore more costly SARCOM. Since the above result is contrary to the philosophy of trading simplicity in the SARCOM for complexity in the ground station, the following possible solutions to the lane ambiguity problem will be attempted.

SIGNAL-TO-SIGNAL RATIO COMPARISON

This method is based on the fact that the amplitude of VLF signals decreases in strength approximately inversely with distance. Preliminary computations indicate a location accuracy of ± 300 nm at the baseline between OMEGA stations and ± 750 nm at the furthest location from the baseline, which is certainly within the 1800 nm accuracy required. An understanding of this technique may be derived from the following example:

Consider a platform located at some distance P off the baseline of OMEGA station A and B, which might be some 5000 nm apart as shown in Figure 1.

In particular, consider the case where the platform at position P is 1000 nm from A and 4190 nm from B. Let the platform be relocated by 300 nm to position P in a direction perpendicular to the LOP so that position P is approximately 1290 nm from A and 3900 nm from B. Referring to Figure 2, the signal from A then decreases by about 8 dB and the signal from B increases by about 7 dB.

Inspection of the 10 kHz curve in Figure 2 indicates that the change in signal strength per 300 nm (550 km) is generally larger than 7 dB, an easily measurable quantity.

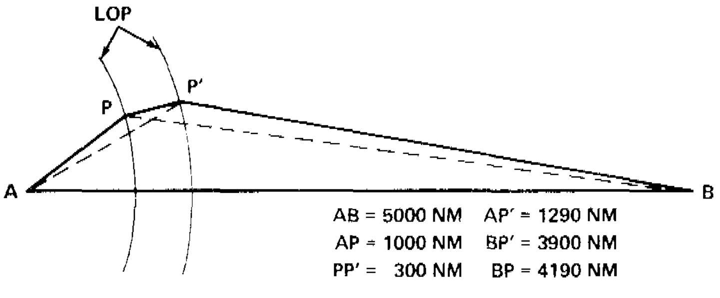

Figure 1. A typical two-station OMEGA configuration.

The two signal-to-noise ratios from A and B are first measured. Since the noise level is constant during the measurement the difference of the two signal-to-noise ratios in dB can be calculated and a hyperbolic line of position obtained.

The OMEGA signal strength will be plotted for several points on the earth to assess the amount of agreement with already collected data.

MULTIPLE LINES OF POSITION (MLOP) (KALMAN FILTERING)

This well known iterative estimation process would utilize the redundant lines of position using signals from four or more OMEGA stations. It may be seen in Figure 3 that three LOP's intersect perfectly only at the true location. At the present four OMEGA stations are in operation and by 1974 eight will be in operation to provide global coverage. Some preliminary results have already been obtained that indicate that this technique is feasible.

DIFFERENCE IN TIME OF ARRIVAL

This technique uses the whole waveform transmitted by the OMEGA stations. The effect is that the ambiguity frequency is ten seconds, the repetition period of the OMEGA transmission. The signals from the two OMEGA stations could, in concept, be cross correlated to obtain the difference in time of arrival; however, the required level of quantization is not practically achievable in view of the magnitude of the ambient noise. To overcome this problem the configuration of Figure 4 is used. A calibration platform is located in the vicinity of OMEGA station A. The signal from station A is transmitted to the satellite through two paths, the calibration platform and the platform P. The cross correlation of these two signals is maximized to obtain the difference in time of arrival τ_1, where $\tau_1 = t_{p1} + t_s - t_{c1} - t_1$. Where these parameters are shown in Figure 4; t_{c1} and t_1 are known, and τ_1 is measured by the correlation technique.

Similarly for the signal from OMEGA station B the difference in time of arrival of the signal throughout the platform P and the calibration platform P is $\tau_2 = t_{p2} + t_s - t_{c2} - t_2$ where t_{c2} and t_2 are known and τ_2 is measured by autocorrelation techniques; subtracting τ_2 from τ_1.

$$\tau_{1-2} = t_{p1} - t_{p2} + t_{c2} - t_{c1}$$

or

$$t_{p1} - t_{p2} = \tau_1 - \tau_2 + t_{c1} - t_{c2}$$

The right-hand portion of the equation is either measurable or known.

Dividing by the propagation velocity we obtain $x_{p1} - x_{p2}$ = constant, where x_1, x_2 are the distances of the platform from A and B. The above equation indicates a hyperbolic line of position with no ambiguity. Obviously this technique requires less than eight calibration platforms.

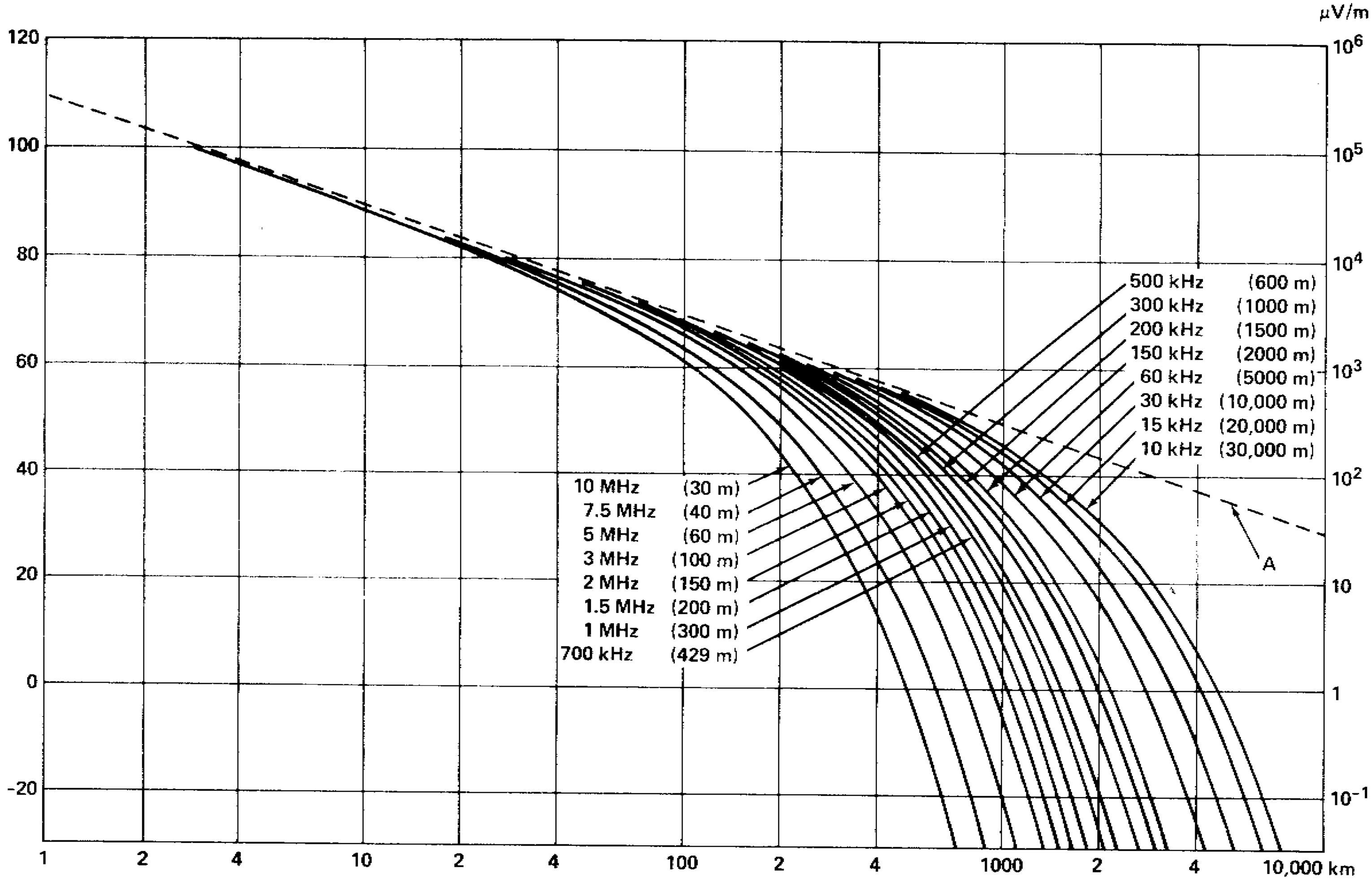

Figure 2. Groundwave propagation curves.

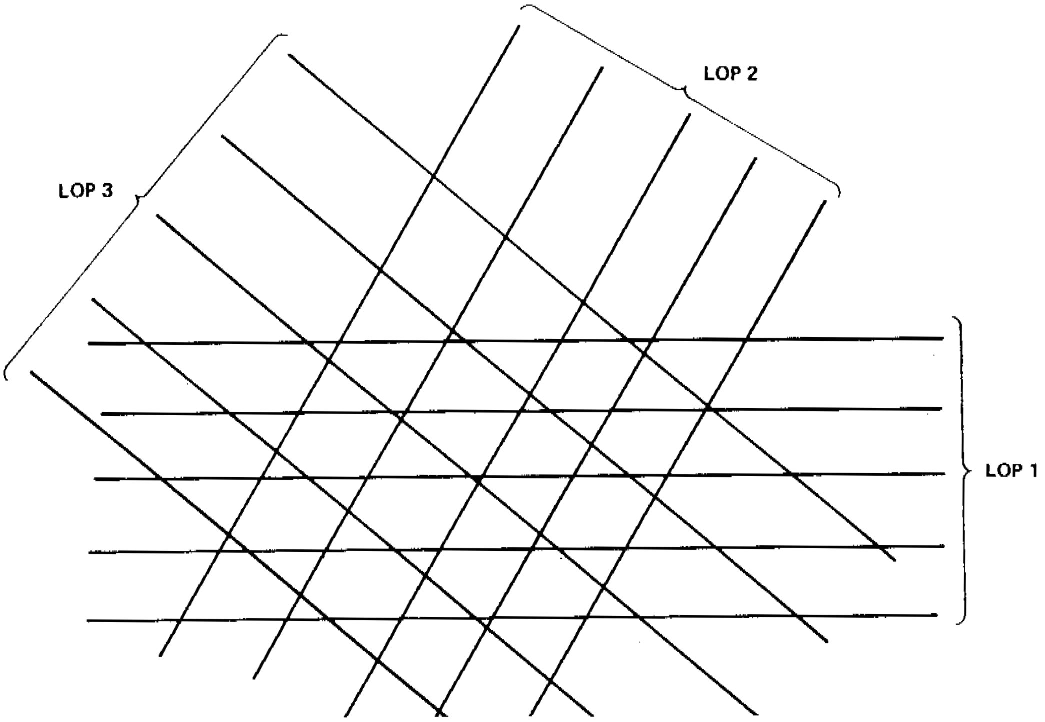

Figure 3. Geometry of redundant grid points.

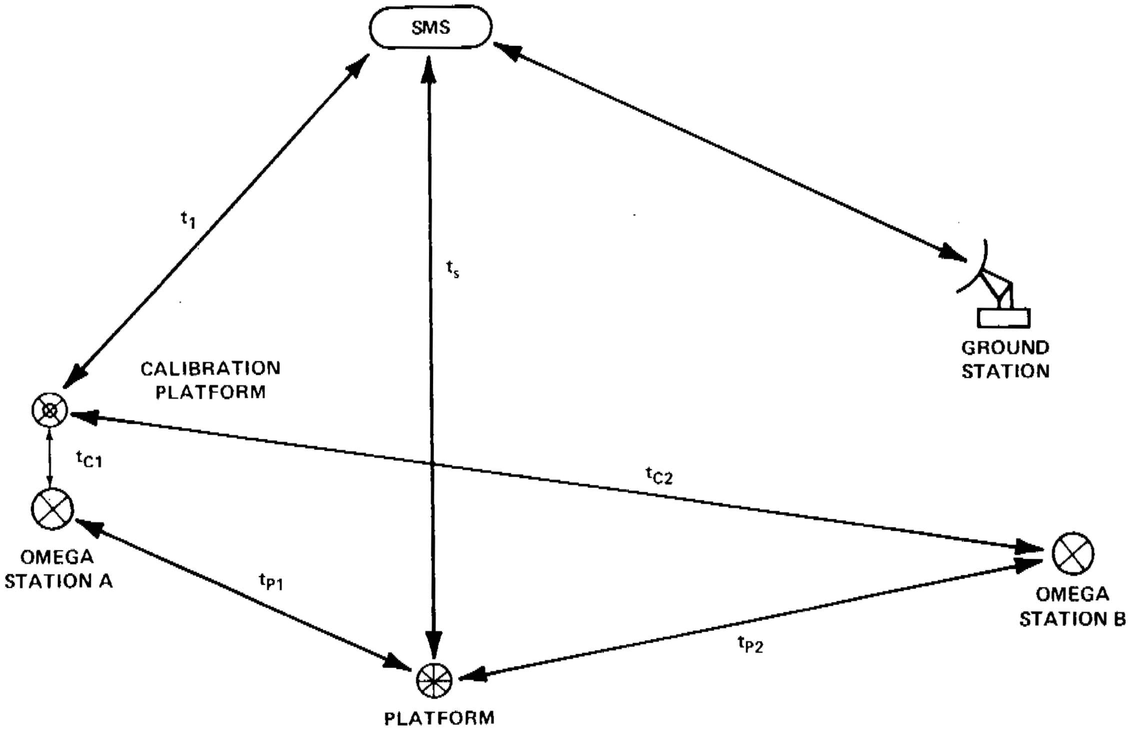

Figure 4. Time-of-arrival technique.

ADDITIONAL OMEGA TONE (10.88 kHz)

The extra OMEGA tone of 10.88 kHz would result in a lane width of 360 nm compared to 72 nm obtained with the present three-tone pattern.

The 10.88 kHz tone is a submultiple of the basic frequency of 816 kHz at the OMEGA ground stations and does not interfere with the existing 10.2 kHz and 11.3 kHz OMEGA tones. Thus, it can be easily implemented by modifying the frequency synthesizer at a cost of less than $100,000.

The difference between 10.88 kHz and 11.33 kHz is 0.453 kHz, while the difference between 10.88 kHz and 10.2 kHz is 0.68 kHz. The difference between 0.68 kHz and 0.453 kHz is 0.227 kHz, which corresponds to the 360 nm lane width above.

The optimum combination of one or more of the above techniques with respect to cost, accuracy, reliability, and complexity are subjects of a current study, which indicates that all of the methods discussed are feasible and can be implemented.

Real-time operation can be achieved by further effort in software and an appropriate increase in the size of the computer. The above-mentioned effort includes a trade-off study that depends on parameters such as CPU size and storage capacity in the computer, software changes, hardware changes and probability of missed alarms due to computer overload.

Presently an rms accuracy of 1 to 2 nm is obtained with OPLE equipment by utilizing skywave correction for the 10.2 kHz tone from published tables and computing a correction (off-line). This method of correction obviously supplies an average error but not the actual error in real world conditions spatially and time-wise. In this experiment for advanced OPLE we intend to deploy several calibration SARCOMs throughout the area of experimentation at known locations. Real-time propagation data from these platforms will supply the control center with spatial and time information on the skywave propagation error that will enable us to increase the location accuracy. (It is possible that these platforms could be used for ambiguity resolution by correlation and differential OMEGA techniques between the calibration SARCOMs and the distress SARCOM.)

Further improvement in accuracy will be achieved by more efficient VLF signal handling and antenna design at the SARCOM to enhance the VLF signal handling and antenna design at the SARCOM to enhance the VLF signal-to-noise ratio.

To increase subscriber capacity presently the WARC has allocated 100 MHz at VHF (at 406.0 MHz to 406.1 MHz for uplink search and rescue application). The present SARCOM utilizes 2.5 kHz for its information bandwidth, thus resulting in 40 search-and-rescue channels. As the number of users becomes larger, the probability of simultaneous transmission increases, thus increasing the risk of two or more users transmitting in the same channel during the same transmission time interval. This risk can be decreased by decreasing the transmission interval or the bandwidth required. The former will result in lower accuracy and the latter may increase the complexity and power requirements at SARCOM. This is clearly a trade-off problem. Preliminary results indicate that with one hundred available channels and five or more simultaneous alarms, the probability of two or more SARCOM being on the same channel is about 5 percent. This trade-off analysis will require more data on accident statistics which will be supplied by the U.S. Coast Guard. The determination of cost functions or pertinent parameters such as false alarm, missed alarm, and so on will facilitate decisions on system design.

SUMMARY

The techniques outlined in this paper should not be considered finalized at this time since the experiment itself will be used as a vehicle to perform optimization and trade-off of the various possible solutions to the search and rescue problem.

The Development of an Advanced OPLE concept will also offer a capability for other user applications. It is anticipated that interest will be solicited among data collection users for additional experiments. The U.S. Naval Oceanographic Office has a requirement for real-time buoy tracking experiments to improve ocean current forecasting techniques. Interest has also been expressed by scientists in meteorology and ecology for a real-time data gathering system.