PROGRESS OF THE DEVELOPMENT OF WHALE ECOLOGY OBSERVATION SATELLITE SYSTEM

T. Hayasahi,
Chiba Institute of Technology,
Narashino, Chiba, Japan
H. Tomita,
Japan

Abstract

To reveal the ecology of some of the species of whales a Whale Ecology Observation Satellite (WOES) System are being developed, in which several ideas are exploited to realize a system with high cost performance.

1.Introduction

For the conservation of whales ecological data of whales are essential, however, those data are not yet sufficient for some of the species of whales. To solve this problem, we are developing a Whale Ecology Observation Satellite (WEOS) System. Its design concept was presented at the Small Satellite Conference, Utah State University in 1995, progress of the development since then along with the total plan will be described here.

This system is comprised of three segments:

(1)A dedicated small satellite in a polar orbit for data collection of whales and data transmission to a ground station,

(2)probes attached to plural whales for sending ecological data to the satellite,

and

(3)a ground station for tracking and operation of the WEOS.

To reduce the cost for realizing this idea, we are developing the whole system along the fol-low-ing guide line :

(a)To positively adopt reliable parts for consumers' electronics into the satellite subsystem associated with sufficient environmental tests,

(b)to apply some of the matured technologies developed in Radio Amateur Community to the design of the communications system,

and

(c)to make use of students' power for measurements and tests of subsystems.

2. Data transmission System

Based on a prospect on the frequency allocation for communications, the system design has changed somewhat from that of the previous paper. The scheme on the data transmission and communications systems are shown in Fig.1, and Table 1 respectively.

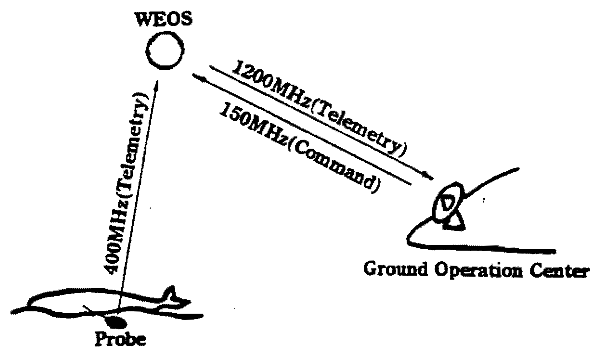

Fig.1 General Scheme of Data Transmission

Communications links are summarized in the Table 1.

Table 1. Communications Links

From	To	Freq.	Comm. Sys.
Whale	WEOS	400MHz	NRZ-S Conv. BPSK Bit rate 300bps Symbol rate 600bps
WEOS	Ground Station	1200MHz	NRZ-S BPSK 1200bps
Ground Station	WEOS	1500MHz	NRZ-S FSK Manchester 1200bps

3. The Satellite (WEOS)

3.1 Configuration

Configuration of the WEOS on the orbit is shown in Fig.2. The attitude of the axis will be stabilized as to point the center of the earth, and communications link will be established. Some of the nutation left will be reduced by using a control software combined with a geomagnetic sensor and magnetic torquing coils.

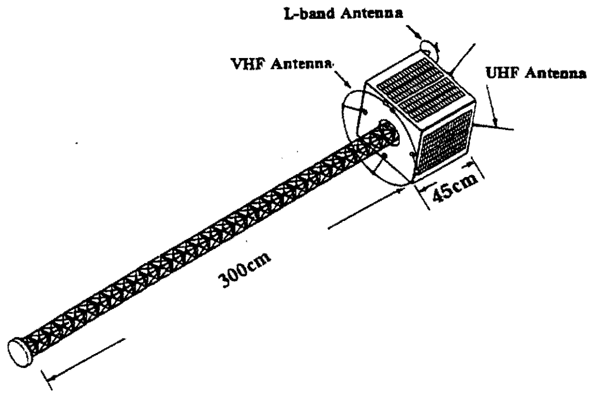

Fig.2 Configuration of WEOS

3.2 Communications System

Block diagram of the WEOS is shown in Fig.3. Since unfavorable condition is foreseen for the reception of the uplink signal in 400MHz from the probe, phase lock loop system is applied to the UHF receiver. The system of the receiver is double super heterodyne and the modulation scheme is PCM(NRZ-S)-BPSK, and its frequency is 300bps with convolutional coding.

The demodulated whale ecology data in base band are sent to a processing unit (WCU) and are stored in a solid state memory.

At the reception of a command uplink signal in VHF from the ground station, the command signal is decoded in the processing unit. The ecological data in the memory is read out by command, and are formatted into the UI frame of AX25, which is compatible to the Reception System of the Radio Amateur Community.

The length of the format for an individual whale is set to be 100 Byte as shown in Fig.4.

FLAG	ADDRESS	CONTROL	PID	INFORMATION		FLAG
01111110	112 bit	8 bit	8 bit	8*N bit	16 bit	01111110

Fig.4 Frame Format (UI Frame)

In the 112 bit of address. 7 Byte of the Call Sign of the Ground station and 8 bit of the identification for an individual whale are included.

The information segment consists of 100 Byte data, in which 22 Byte of House Keeping data and 2 sets of 39 Byte whale ecology data are included, as shown in Fig.5.

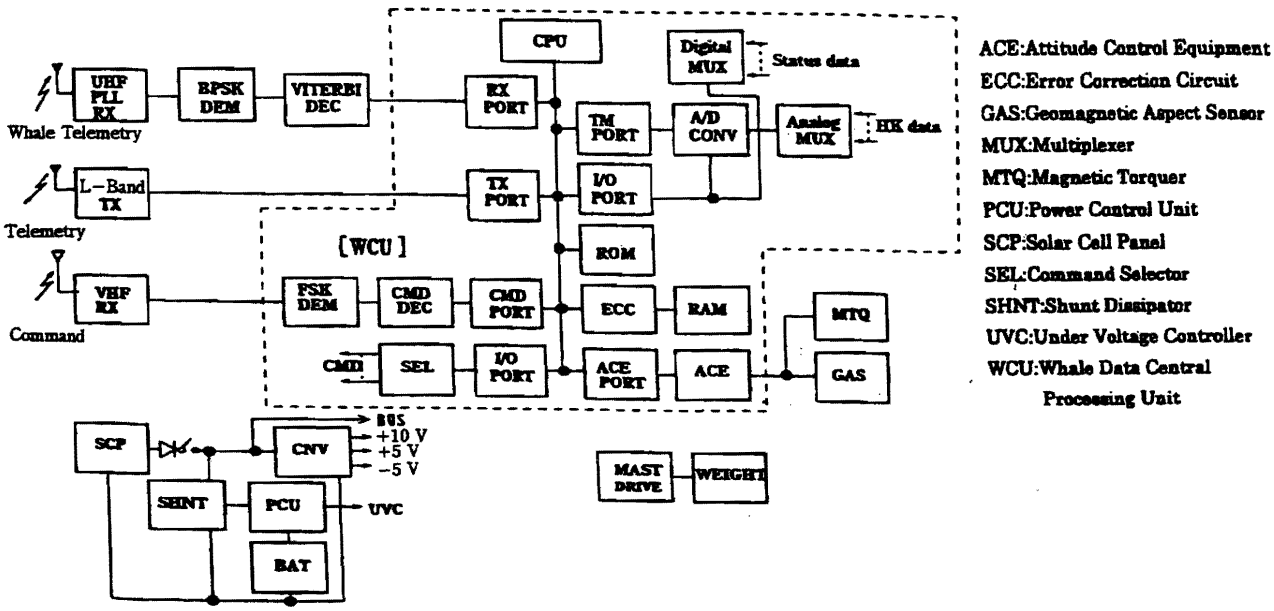

Fig.3 Block Diagram of WEOS

House Keeping and Status Data of the WEOS	Whale data	Whale data
22 Byte	39 Byte	39 Byte

Fig.5 Information Segment

Those data are edited and are sent in 1200 bps by an L-band transmitter of 0.5W in the modulation of PCM(NRZ-S)-BPSK to the ground station.

3.3 Structure

Structural concept of the WEOS is shown in Fig.6 as an explosive view.

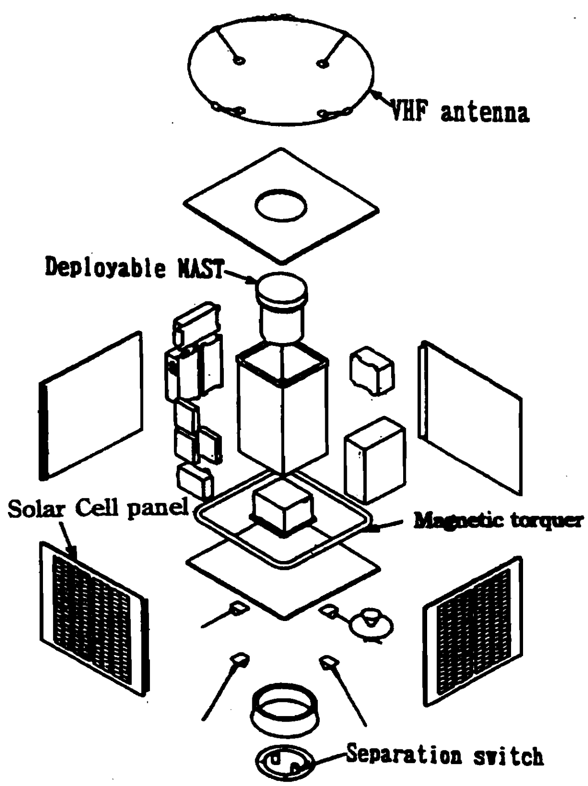

Fig.6 Explosive View of WEOS

4. Probe

4.1On board Instruments

Several sensors for collecting whale ecology data are installed in a probe. They are pressure temperature, geomagnetic field, and acoustic sensors, along with a GPS receiver as the position sensor.

The data obtained in the depth are stored in a memory. When the whale surfaces the data in the memory are sent together with the position data of GPS to the WEOS by a telemetry in 400MHz band.

The electric power for the instruments are generated by a generator utilizing swing motion of the probe. which is caused by the motion of the whale. This is an application of a system. which is practically utilized as the power source

of a quartz type wristwatch developed by Seiko-Epson Co.

Block diagram of the probe system is shown in Fig.7,in which scheme on the turn-on operation of subsystems corresponding to the role of each measuremen is depicted.

All of the instruments including antennas will be installed inside a plastic casing to avoid the troubles caused by corrosion or contamination in the sea water. For some species of whales,for example sperm whales,the structure of the probe should be designed to withstand the high pressure to meet their deep diving.

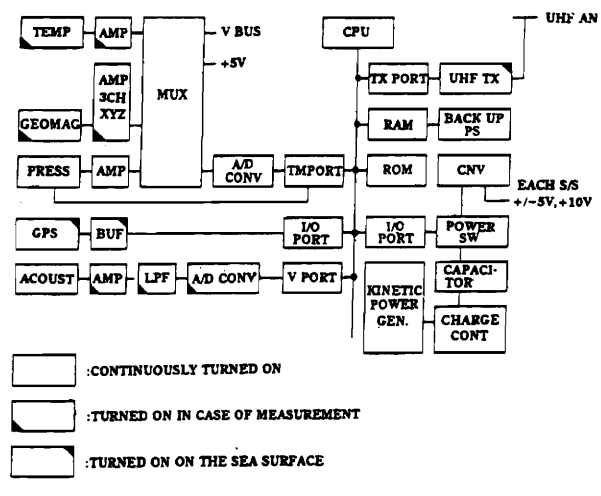

Fig.7 Block Diagram of the Probe System

4.2 Data Transmission

To form an efficient communication link between the probe and the satellite a PLL receiver is installed on board the satellite. For the aid of easy lock-on of the receiver. uplink signal from the probe is arranged as shown in Fig.8. No signal interval for 1.5 second just before the unmodulated signal serves for the receiver to detect and avoid interference signal by an aid of a logic in a DSP in the UHF receiver on board the WEOS.

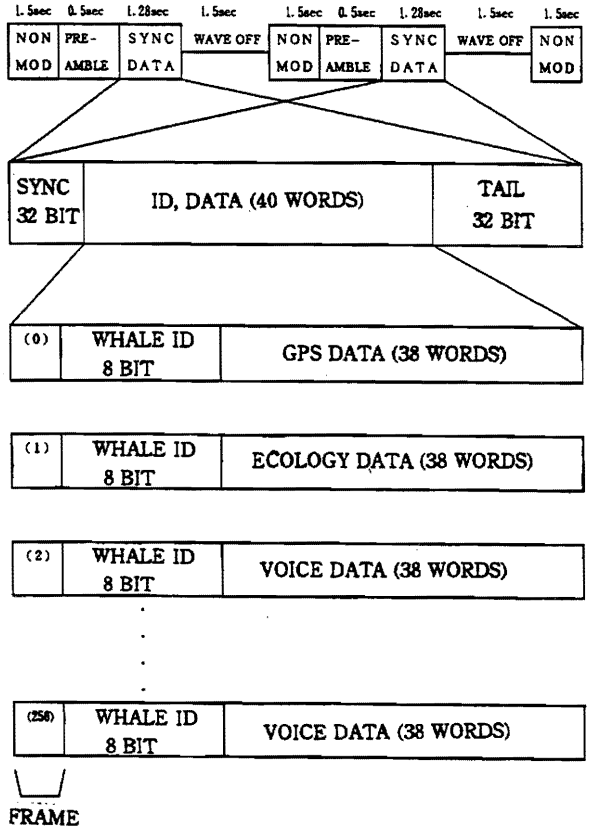

Fig.8 Data Transmission from Probe to WEOS

Sensor data dispersed lock- on aid are connectedly shown in Fig.9.

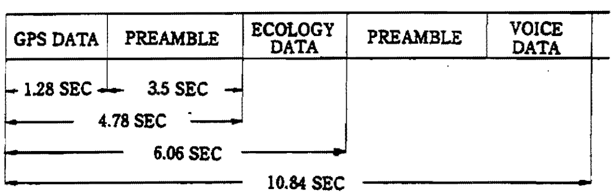

Fig.9 Net Data Stream from Probe to WEOS

There are two units of solid state memory, for writing (A) and for reading (B). The contents of the memory are shown in Fig.10 .

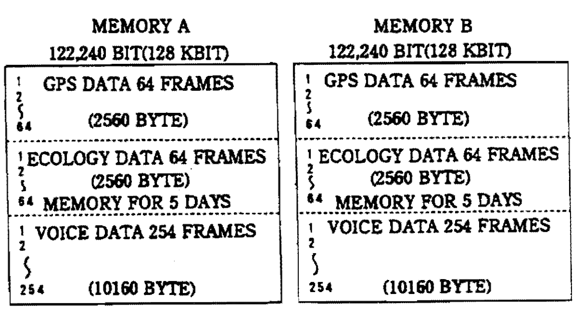

Fig.10 Memory Units in the Probe

4.3 Power Generator

Kinetic power generation is studied by using a motion simulator in which frequency and other parameters are adjustable. (Fig.11)

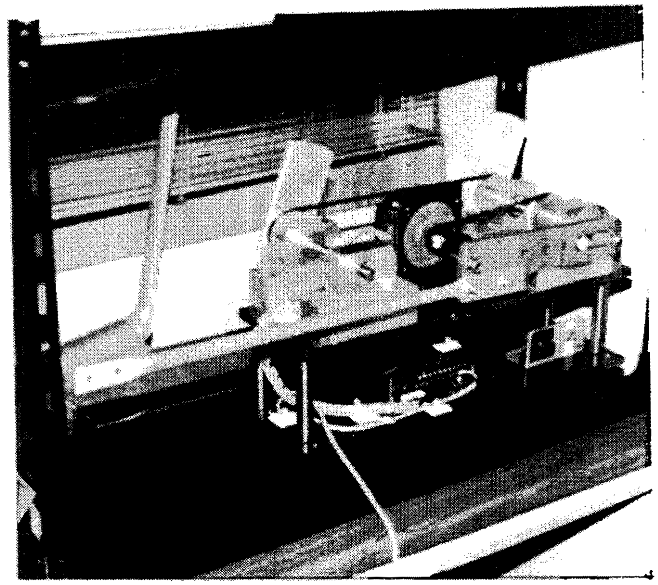

Fig.11 Motion Simulator of the Probe

The most favorable motion for generating power will be reflected to the outer configuration of the probe, for example by attaching a vane with a proper shape.

4.4 Attachment of the Probe

To expect stable attachment of the probe for a few years, the harpoon should be as gentle as possible for the living body. A small harpoon made of Titanium is shot by an airgun. Several barbs made of shape memory alloy are fixed at the top of the harpoon. The phase transition temperature of the barbs is set to be 30℃. A quarter of circle is memorized as the shape of the barb at higher than this temperature. When the harpoon is shot into the muscle of a whale, since the bodily temperature of the whdfale is 37℃, in case of any drag, the harpoon will be anchored by the warmed up barbs on the fascia under the blubber. In the previous paper usage of barb wire made of shape memory alloy was reported, but to reduce the pressure on the individual barb surface, the wire was replaced to a plate as shown in Fig.12.

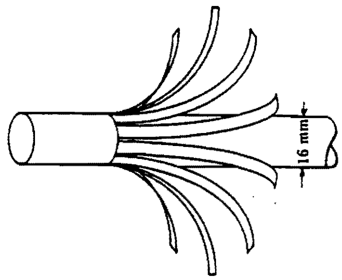

Fig.12 Barb Plates of Harpoon

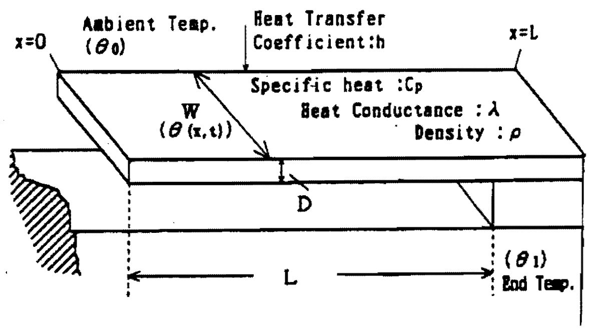

Fig.13 Mathematical Model of Barb Plate

Based on mathematical model of Fig13. The thermal time constant of the barb is estimated as shown in Fig.14.

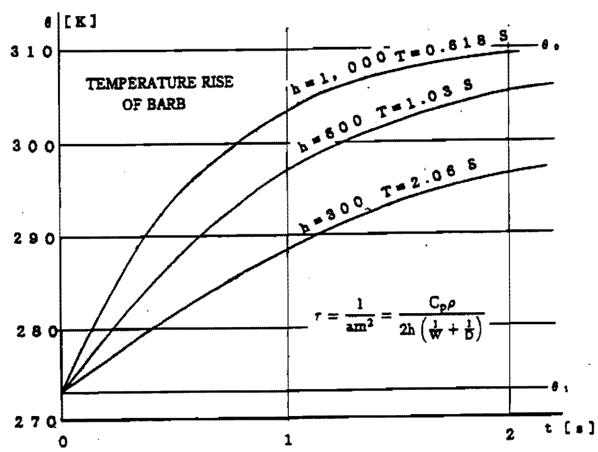

Fig.14 Estimation of Thermal Time Constant

A scheme of attachment of harpoon is shown in Fig.15 (a). A cord is fixed after the harpoon, and on the tail end of the cord a small ring is fixed . A long cord is put through the ring just like a thread through a needle hole,and both ends of the folded cord are still left on a boat. To one of the ends a probe is attached .and if the free end is pulled. the probe will approach to the ring after the harpoon. and finally will be fixed to the ring by a clamp. as shown in Fig.15(b).

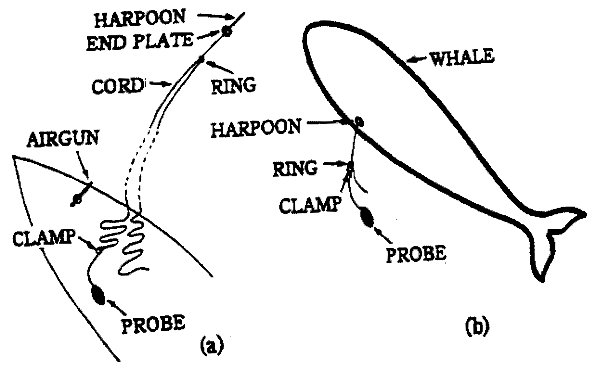

Fig.15 Scheme of Probe Attachment

Thus a proper length of cord between harpoon and the probe is realized,and expected time interval of several seconds between the insertion of the harpoon and the clamp of the probe will allow the rise of the temperature of barbs to be higher than that of the phase transition.

5.Ground Station

The telemetry signal in L-band is converted to 28 MHz by a frequency converter. This is one of the frequencies allocated to the Radio Amateur Community. Thus a matured technology for the receiver in Amateur Band along with a Terminal Node Connector(TNC),which is also a familiar tool for the Packet Communications in the same community. are applied to the receiving system. and a ground station with high cost performance is to be realized.

Set up and adjustment of the ground system is now conducted by the collaboration of several students.

6.Conclusion

Development of the Whale Ecology Observation Satellite System is proceeded steadily aiming its piggy back launch in a few years.

To clear the migration pattern of whales. we have to make the probe stay at least for one or two years. For this purpose we are designing the harpoon as gentle as possible for not so much bothering the behavior of the whales.

If probes were successfully attached to plural whales and their migration patterns were plotted on an atlas together with several sensor data. we would be able not only to get the information on whale ecology in detail, but also to expect to obtain a lot of unknown under the ocean through the density distribution of many tracks of whales.

References

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