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Environmental Module System for DUMAND: Design and Deployment

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INTRODUCTION

The Environmental Module (EM) system planned for DUMAND-II is required to provide location data for the Optical Module (OM) strings sufficient to permit reconstruction of muon tracks with 1 deg precision in terms of celestial coordinates. In practice, this involves two separate tasks:

1) determine the relative (site) coordinates of the OMs with approximately 10 cm precision, at time intervals which depend upon the motion of the array in ambient currents;

2) determine the angle between the site coordinate axes and absolute geographic north to better than 1 deg, and the absolute geographic coordinates of the site origin to within <<1 deg of longitude (a few hundred meters).

The first task may be described as the runtime positioning problem, and the second is the site survey problem. Both will be solved using acoustical ranging techniques, although different methods and in some cases separate equipment will be used. In the DUMAND lexicon, these functions have been referred to as the environmental module task because ocean environment data are required for the determination of sound speed.

To accomplish these tasks, 5 types of equipment will be supplied by UW:

1) **Junction Box EM (JBEM)**, a special string of equipment mounted on top of the JB, including a set of three hydrophones, a pinger, an environmental sensor unit (Neil Brown Unit or equivalent CTD meter), tiltmeter, compass, as well as two video cameras (one fixed, one with tilt/pan mount) and lighting system;

2) **String EMs (SEM)**, comprising a set of 5 hydrophones and preamplifiers mounted at intervals among the OMs, and an electronics module to digitize the hydrophone signals and pass them to the SBC for transmission to shore via the string data stream;

3) **Enhanced SEMs**, (EEM) in which a CTD meter, tiltmeters, and a GESPAC computer controller are added to the basic SEM complement;

4) **Hardwired responder network** for runtime positioning, consisting of 5 pinger/hydrophone modules connected to the JB by 4-conductor copper cables;

5) **Autonomous expendable transponders**, deployed in an outlying configuration for site survey and deployment of the JB and responders.

The latter three items will have obvious impact on the JB design and deployment procedure. The purpose of this note, in addition to communicating recent changes in the planned approach to the acoustical positioning problem, is to suggest a strawman deployment procedure for further discussion.

JUNCTION BOX EM

The junction box will carry the JBEM string, connected to the shore data stream by its own optical fiber. In addition to providing a Neil Brown Unit (conductivity, temperature, density, and current meter), the string will carry a pinger and three hydrophones in a triangular configuration. The latter will provide an in situ estimate of sound speed, independent of the value calculated from CTD data. A tiltmeter and compass will be included to provide data on string motion, giving a preliminary idea of the effects of currents at the site prior to string deployment. The GESPAC computer and its associated hardware (multiplexers and ADC boards) will constitute the JBEM Controller (JBEMC) module. Due to the large number of cable feeds required, we will house the JBEMC in a cylindrical metal can. Fig. 1 shows the physical layout of the JBEM string. Figs. 2 and 3 show block diagrams and cable interconnects for the JBEM system as a whole, and the JBEMC subsystem.

The JB string will include a video system to aid JB deployment and connector mating during string deployment. Two monochrome CCD cameras with shore-controllable focus and iris will be mounted on a crossbar member about 5m above the JB, one with fixed aim toward the top of the JB and the other on a tilt/pan head. Long-lifetime high efficiency vapor lights will provide illumination for the video system. The JB-EMC will pass the slow data (multiplexed hydrophones, NBU and tiltmeter) to shore via a TAXI link into the JB dedicated optical fiber. However, two simultaneous video camera signals will saturate the TAXI serial link capacity; hydrophone data must be shut down if both cameras are operating, but this should not be a problem since JBEM hydrophone data may not be required during deployment. If a deployment scenario evolves which requires simultaneous operation of both cameras and the hydrophones, we could provide reduced resolution on camera digitization (e.g., 256 pixels/line instead of 525). Onshore, the digitized video will be buffered out of the data stream rollover words and reconstituted using a DSP signal processor board resident in the EM data processor CPU. The reconstructed analog video signal can then be viewed onshore and relayed to the deployment vessels by normal communications channels.

STRING EMs

Although the 1988 DUMAND-II Proposal described three hydrophones per string, this number is just sufficient to indicate curvature, and five hydrophones are required for overdetermined fits to the expected catenary string shape, as well as providing redundancy for long-term operation. Benthos hydrophones with integral preamps will be used, connected to the SEM module by threeconductor cables (twisted pair with shield). Fig. 4 shows a block diagram of the SEM, which will digitize hydrophone signals with 100 kHz sampling and pass the multiplexed data (0.5 MHz) to the SBC using a TAXI high-speed serial link with 150 Mbd capacity. High resolution signal sampling will permit pulse timing via waveform fits rather than leading edge detection. This means that low-frequency range (10--20 kHz) pingers and hydrophones can be used and still provide <0.1 msec timing resolution, as discussed below. High frequency equipment (30 kHz or greater) has shorter effective range and higher cost. The SEM electronics will digitize and multiplex hydrophone data autonomously and pass the data to its SBC via coax cable, so no CPU is required for the SEMs.

ENHANCED EMs

We expect to deploy two SEMs and one EEM in the initial triad, with the next six strings including 5 SEMs and one additional EEM. The EEMs will have a tiltmeter/compass combination at two points between hydrophones, providing a check on whether additional points of inflection exist between acoustically measured positions. If results of triad operation indicate this is a frequently encountered situation, the remaining 6 strings could have extra hydrophones added. The EEM will also carry a Seabird environmental sensor package (measuring conductivity, temperature and density), and a GESPAC 68000 computer will be used to read the tiltmeter, compass and CTD meter data into the hydrophone multiplexer for transmission to shore. The EEMC will pass data to its SBC via a TAXI serial link identical to that used by SEM units. As with the JBEM, the GESPAC and associated electronics will be housed in a metal can. The functional diagram for EEMs will be identical to that for the JBEM and JBEMC (Figs 2--3), except for the absence of video cameras and associated external equipment.

TRANSPONDER/RESPONDER NETS AND SITE SURVEY

The runtime positioning scheme involves determining the range from a given string hydrophone to 4 or more pingers (surveyed fiducials), allowing simultaneous overdetermined fits to the three hydrophone coordinates and the sound speed. These fits will be performed by nonlinear regression using detailed data on the sound speed profile over the experiment depth range, and with initial values based on sound speed calculated from CTD data. Since the scheme depends upon fixed fiducials, the pingers must be mounted on tripod supports, or tethered with sufficient flotation to hold their drift circle to within 10 cm radius. A rough calculation suggests that 100 lb positive buoyancy on a 10 m tether (assuming a low-drag shaped float) will be adequate. Placement about 10m off the bottom will be required to avoid corruption of pulse arrival time determination by prompt bottom reflection signals. Preliminary calculations indicate that a mean radius of 300m from site center will be appropriate for the fiducial network. We plan 5 units, to provide redundancy. The

JBEM pinger acts as a 6th fiducial nearer the array center.

No commercially available transponder has demonstrated battery lifetime greater than 6 yr. Since the initial surveying-in of the transponder network represents a substantial investment of effort and ship time, we plan to use hardwired pinger/hydrophone units (responders), attached to the JBEM by 4-conductor copper cables with underwater-mateable connectors. This scheme eliminates problems imposed by the limited capabilities of onboard electronics in self-contained transponders, which perform pulse leading edge detection by analog filtering techniques. For this reason, transponders which provide ranging resolution <10 cm must operate in the high frequency range (50--100 kHz) and thus have limited range and high cost. Since the responders are powered by the shore cable, there is no lifetime limitation. Since pings are commanded from the shore computer, delays are known precisely.

Installation of the JB and the responder net, and surveying an accurate north-south axis, will require a temporary transponder network. We can use the Oceano expendable transponders already on hand in Hawaii. These will be deployed with a 1 km nominal radius from the site center and surveyed using shipboard GPS relative positioning, accurate to about $\pm$ 2m with appropriate shore station referencing. Fig. 5 shows the nominal layout of the fiducial network relative to the array. Axes equidistant between transponder pairs can be located precisely using a null method suggested by H. Bradner: surface positions with equal arrival times are plotted. Arrival delays from transponder pairs should integrate over the same water layer properties (to the extent that horizontal CTD variations are negligible over the few km horizontal span of ray paths) and thus arrival time <u>differences</u> should be independent of sound speed stratification effects. Once the bisector lines have been determined, the orientation of the temporary transponder network relative to geographic north is fixed and can be used to reference the responder net. The transponders will also allow accurate placement of the JB relative to mapped bottom features. Since placement of these transponders is not critical, they can be allowed to free fall from nominal drop points. It may be useful to place them during a preliminary cruise prior to JB deployment, since the GPS survey will be time consuming, and they can serve as site markers for camera sled runs and other site definition work. When they fail due to battery lifetime, new units can be deployed and surveyed relative to surviving units.

The responders will be deployed at approximately 300m radius from the site center prior to string deployment, and the submersible will be used to connect them. They can then be surveyed in relative to one another and to the outlying transponder net by conventional ranging techniques, since sound ray paths will be confined to a horizontal layer with properties monitored by the JB's Neil Brown unit. Relative positions will be determined to within a few cm, and the transponder net will provide a connection to absolute geographical orientation.

Ranging will be accomplished by using our onshore computing power to filter noise and fit ping waveforms. Such fits will provide pulse arrival time resolution better than one cycle, i.e. delta-t <~ 1/f. Conventional commercial locating systems use simple signal thresholding techniques to determine pulse arrival times, and thus have precisions corresponding to many full cycles; high frequencies (30--100 kHz) are required to provide 0.1 m positioning accuracy. Since absorption is a strong function of frequency, HF systems have effective ranges on the order of 500m and cannot be used for long-baseline nets. In our case, the responder and transponder frequencies can be in the low to medium range: 15 kHz provides 10 cm resolution if we can only fit to ±1 cycle, and we should be able to do better. The use of LF equipment results in substantial component cost savings as well as permitting operation over a 2 km baseline as required for the geographical orientation specification.

JBEM PHYSICAL LAYOUT

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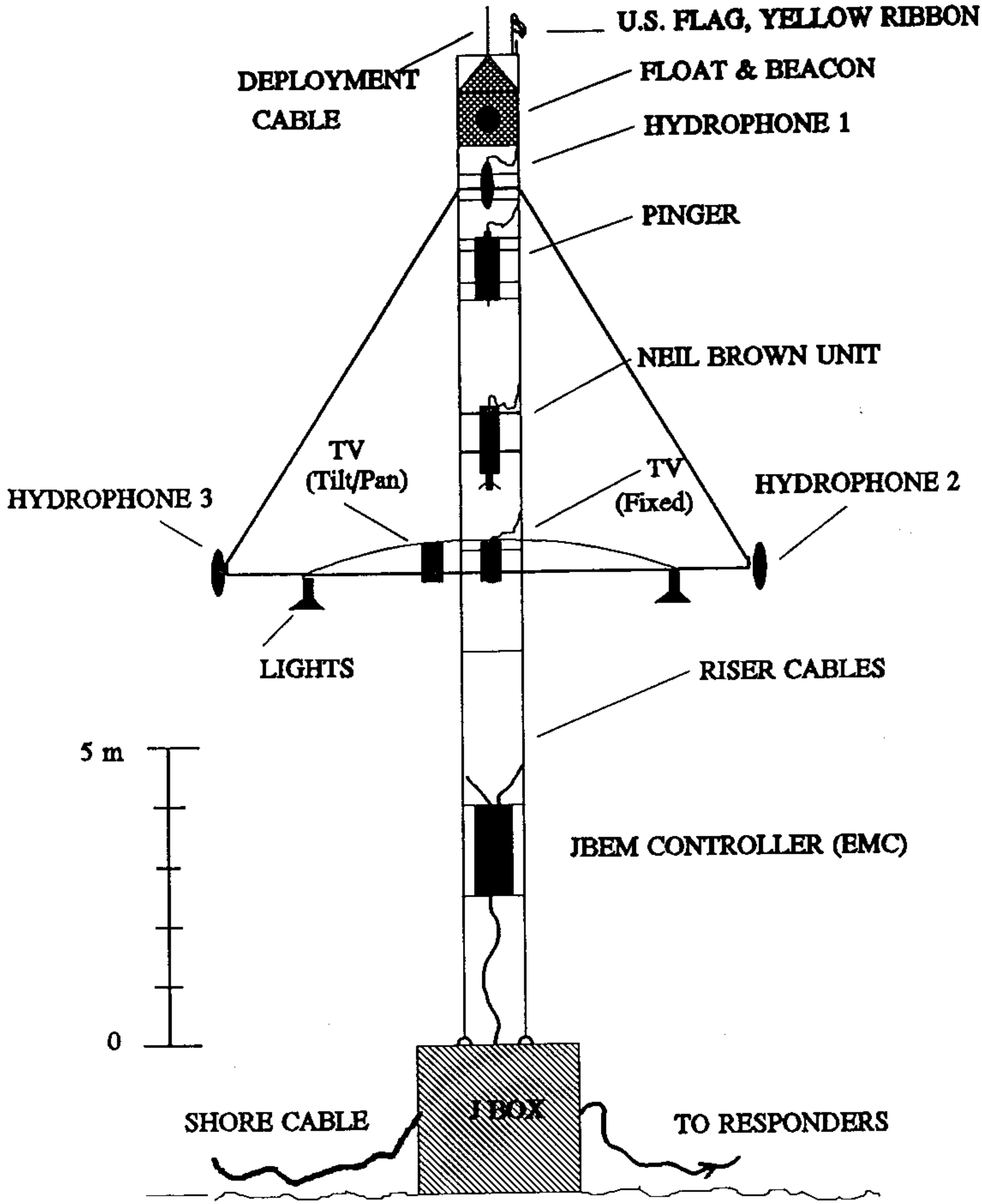
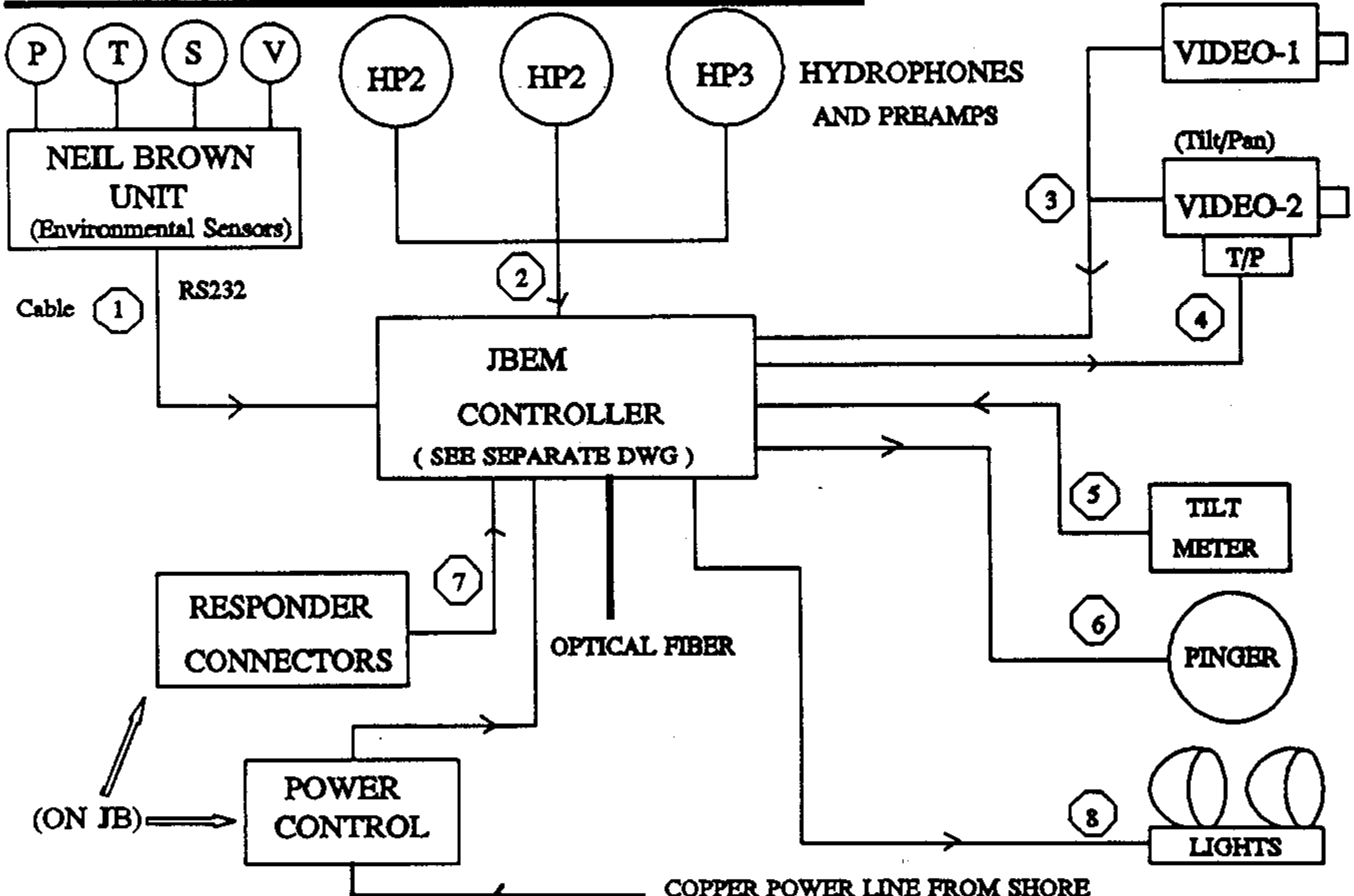
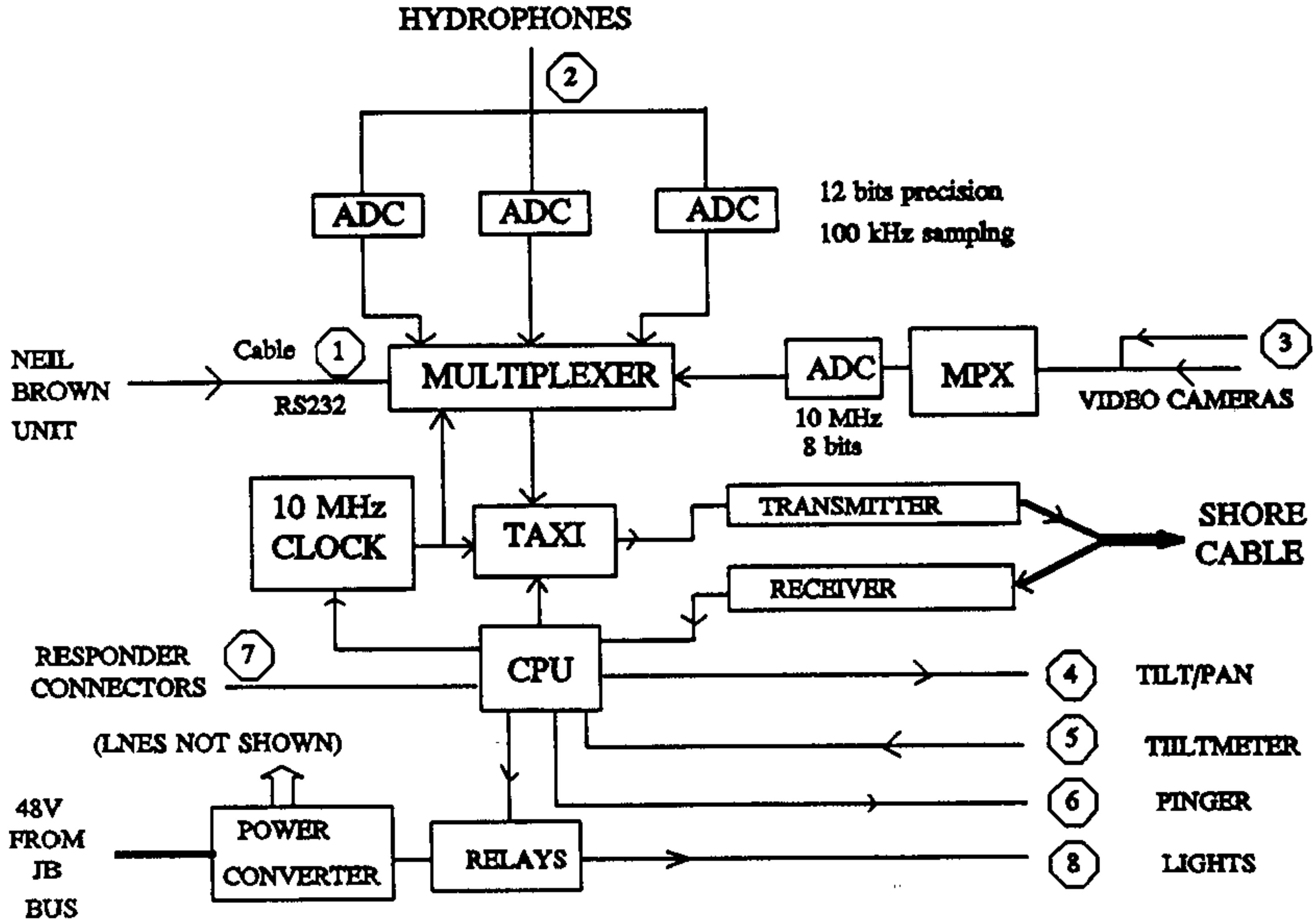


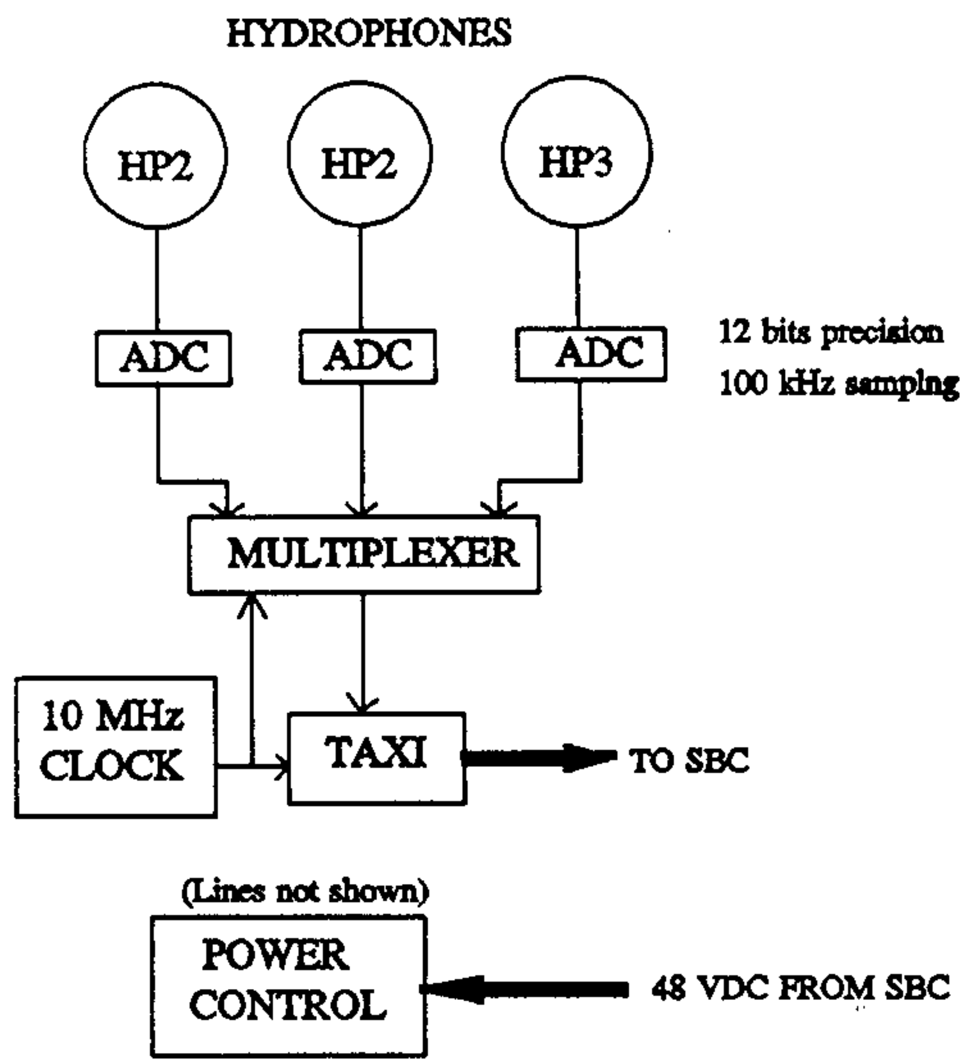
JBEM BLOCK DIAGRAM RJW, 2/11/91

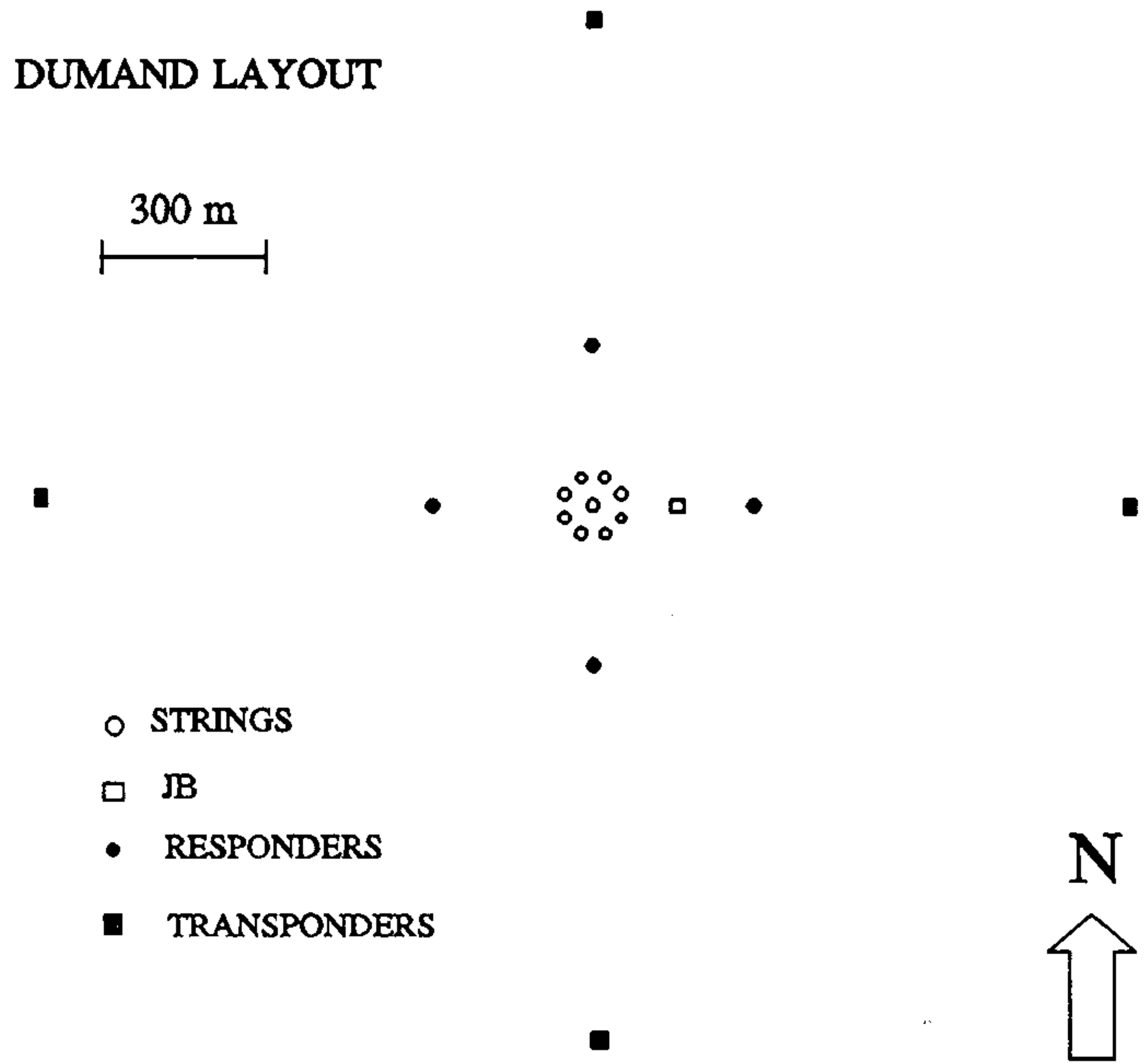


JBEM CONTROLLER DIAGRAM RJW, 2/11/91



STRING EM BLOCK DIAGRAM RJW, 2/91




DUMAND LAYOUT
300 m
STRINGS
JB
RESPONDERS
TRANSPONDERS
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