A Digital Radiosonde System
with
Open Architecture

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ABSTRACT

At a time when the condition of our planet's environment, due to past and present abuses, is becoming critical, we find that funds are not being appropriated in sufficient amounts for taking effective counteraction. The inability of debtor nations and the unwillingness of the industrialized nations to address the problem squarely poses a challenge of unprecedented proportions to the scientific community. The world's atmospheric data collection program is no exception and soon may find itself on the endangered species list. This paper describes a concept in equipment and radiosonde design that should provide a partial solution to the dilemma.

1. INTRODUCTION

The discussion contained in this paper is based upon four premises. If these are accepted then the reader should be persuaded to reach similar conclusions to those given at the end of the paper. The four premises are:

(i) That the atmosphere is being stressed by numerous pollutants, the carbon dioxide content shows a relentless long term increase, the ozone layer is undergoing significant changes, rain forests are being depleted in an uncontrolled manner, and aerosol transport and precipitation is affecting agriculture in many countries;

(ii) That debtor nations, of which the United States is now one, have withdrawn, or are in the process of withdrawing financial support for atmospheric and environmental programs and that financially strong industrial nations have their priorities elsewhere;

(iii) That in the political arena, insufficient importance and urgency is given to environmental and weather oriented programs. Long range impact is not within the time frame of most political administrations and scientists do not always make consistent and persuasive arguments for funding appropriations;

(iv) That neither satellites nor terrestrial remote sounding techniques currently satisfy the requirements for modeling or forecasting, a condition that is not expected to change until the turn of the century, and that in-situ measurements are essential and fundamental to forecasting and a fuller understanding of the planet's weather engine.

2. COST OBJECTIVES

The cost of acquiring, installing, operating and maintaining an Upper Air Station is substantial, and often misrepresented by simplification. If we are to perform a meaningful analysis, costs should be established on the basis of providing acceptable and timely data to the end user rather than assessing out-of-pocket expenses for the procurement of goods and services. Two classes of cost exist - those associated with the installation (non-recurring) and those pertaining to daily operation (recurring). Costs falling into these categories are listed below.

Non-Recurring

Facility Procurement
Ground Equipment
Facility Preparation
Spares
Initial Training
Installation
Commissioning
Shipping
Customs Duties
Taxes
Commissions

Recurring

Facility Utilities and Maintenance
Labor
Retraining
Expendables
- Radiosondes
- Gas
- Balloons
- Parachutes

Equipment Maintenance
Spares
Vendor Support and Service
Shipping
Taxes
Customs Duties
Commissions

Both categories of cost can be defined as either direct (labor and materials) or overhead (shipping, training, taxes, duty, commissions, services). The cost objectives for the supply and use of new equipment and expendables are two-fold - (a) to minimize all overhead expenses, since these contribute neither to the manufacturer of equipment and expendables nor the user, and (b) to transfer a portion of the direct cost to the country in which the station is located (indigenous manufacturing labor and materials). With these economies and arrangements, purchases, profitable to manufacturers, can continue to be made while lowering the cost of data acquisition. It is with these motives that the subject equipment and radiosondes have been designed.

3. RADIOSONDE MANUFACTURING

3.1 The Market

Upwards of 80% of the world's supply of radiosondes are produced by fewer than ten manufacturers and this number is getting smaller. It is important for the meteorological community to recognize and understand the reasons for this and to appreciate the challenges facing the radiosonde manufacturer today. The world requirement for radiosondes for synoptic, scientific and military use, in marketing terms, is static or even shrinking. Added to this the user community is demanding higher accuracies and consistency while insisting upon price stability. From a corporate standpoint this translates into "no growth and reduced margins" and should be considered as an unsatisfactory product for contribution to corporate well being. The fixed market signifies that the only movement which can occur is a redistribution of market share based upon price and performance competition . Unfortunately many contracting agencies pay little attention to performance and purchase on price, especially when hard currencies are involved. The net result is price competition that erodes margins and profits to a level that cuts into the expensive and very necessary research and development budgets of the participating companies. Under the classic rules of marketing and free enterprise this would be considered a healthy situation. Market forces would effect stabilizing adjustments to the supply chain. In the case of radiosondes the reverse is more likely to take place.

3.2 Corporate Motivation

If the market is static and margins are being eroded, what then is the corporate motivation for continuing the manufacture of radiosondes? One has only to look at the history of those companies involved to see that there is a strong traditional influence, dedication and an emotional attachment to the meteorological discipline. In the board room of a classic business these factors have little meaning since they do not contribute to profitability. However, if a company that does not have a historical involvement in radiosondes elects to try its hand at radiosonde design and manufacture, through lack of experience it falls short of providing a product that meets the performance requirements of the user . Recognition of the difficulties only surfaces after the initial exposure and thus interest is short lived because of the unwillingness of the corporation to invest substantial assets in a static market with no sign of return on investment. This state of affairs does not bode well for the meteorological community, for it signifies higher prices with a consequent reduction in purchased volume resulting in even higher prices. The source of supply for radiosondes responsive to user requirements should therefore be considered fragile.

3.3 Specialization and Financing

Anybody who has been associated with the design, development and manufacture of radiosondes knows this is a highly specialized product that takes years of research and experience to produce and market at an affordable price with the requisite performance. The manufacturer must have in place a sensor development program to meet the stringent requirements and a continuing simulation and flight monitoring program to assure product conformity. Further the manufacturer must have the staff with the experience to know what constitutes an acceptable product in flight with all the variables of the atmosphere, sensors and electronics simultaneously at work. These capabilities are essential, and the expenses have either to be subsidized or carried by the product. If subsidies are unavailable and the product market price cannot carry an adequate margin, then these activities are reduced or cut to the detriment of the product and the meteorological discipline.

3.4 VIZ

At VIZ we do not have the benefit of any form of independent funding but recognize our responsibility and the need for an active development program. All of the costs associated with radiosonde research and development, production, and flight testing are paid for from revenues created by the sale of radiosondes. With over thirty years of experience in the manufacture of radiosondes, VIZ is one of those companies with the tradition and the dedication to the supply and services for the meteorological community. As evidence of this, VIZ embarked upon an ambitious multi-million dollar development and facility expansion program in 1985 which will be completed by 1990. The ZEEMET Mark II MICROSONDE and a new range of ground equipment, the ZEEMET W-9000 series, are part of this program; their designs are being guided by the market conditions discussed in the previous paragraphs.

4. MORE DATA AT LESS COST

In order to get more money into the data gathering and dissemination process, a number of actions must be taken on both the part of the user and manufacturer to ensure that the available funding is effectively employed. This requires a substantial investment by the manufacturer in product development and production techniques. It also requires the user's cooperation in the procurement process and willingness to make an investment in communication systems.

4.1 Manufacturer's Responsibility

By incorporating current technology in the design of sondes and ground processing equipment and by employing modern manufacturing processes and administrative techniques, manufacturing productivity can be increased, thereby improving margins and stabilizing prices. In addition the manufacturer is essentially in control of the distribution chain and is therefore able to select the best route for goods and services to reach the user. The employment of local licensees of the manufacturer is a particularly effective link in this distribution chain. (Beukers 1984)

4.2 User's Responsibility

The user can become more involved, and, more often than not, use lower cost local labor to manufacture radiosondes under license. Automation of the sounding can reduce facility expenses. Communications for equipment servicing and software updates can have a substantial impact on the reduction of station running costs.

This paper discusses the various aspects of cost reduction but first let us take a look at a system block diagram.

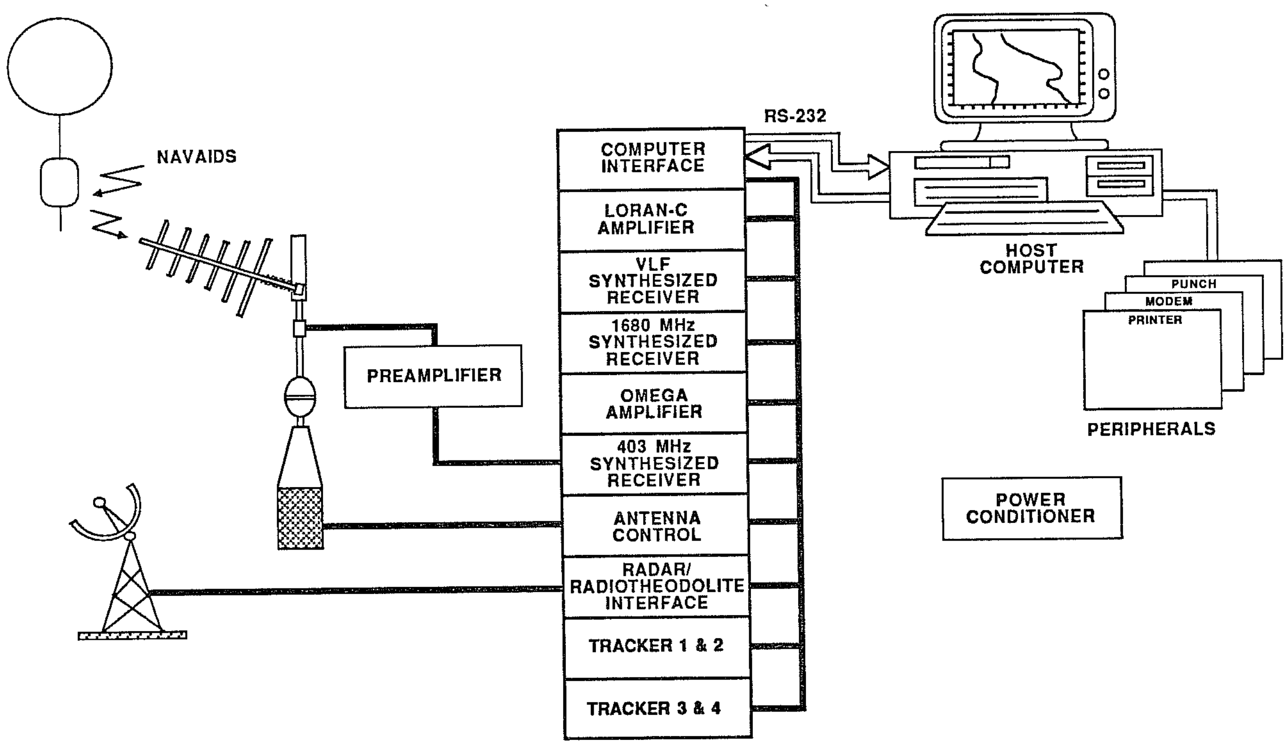
5. THE SYSTEM

5.1 Open Architecture

The term "Open Architecture" (OA) is now common to the computer industry. It means that the manufacturer has endorsed a policy to provide the industry and customers details of the inner workings of the equipment and associated software. In the case of the desk-top personal computers, manufacturers who embrace the principle of OA have placed details of the internal bus structure and operating systems in the public domain. Similarly, OA software vendors provide information relating to the structure and code of their programs for third party developers to generate enhancements to the original program.

5.2 The W-9000 System

With the ZEEMET W-9000, VIZ has made a commitment to a system having open architecture and will provide information that will enable a user to interface W-9000 hardware, using standard protocols, for custom applications. In addition sufficient details of the software will be made available for an understanding and possible modifications or extensions to the standard system software provided. A conceptual block diagram is shown on the next page. This depicts a digital MICROSONDE, transmitting meteorological and navaid data at 400-406 MHz to a dual rotatable antenna (or meteorological data at 1680 MHz to a radiotheodolite.) The received signals are applied to receivers housed in a 19 inch Eurorack assembly that also contains a variety of plug in modules. Signal processing takes place in these modules and the resulting output is sent at 9600 baud to a standard MS-DOS 286 computer (PC/AT), using RS-232 protocol. All of the system commands are executed from the computer keyboard and transmitted to the modules on a second RS-232 communication channel. Standard peripherals are connected to the computer as dictated by the station requirements.



ZEEMET W-9000 System Block Diagram

5.3 The Mark II MICROSONDE

The expendable package contains a 6805 microprocessor which, in conjunction with a masked ROM and associated EEPROM, serves to convert pressure, temperature and humidity information into a binary data stream. Included in the data stream are all calibration constants, the sonde serial number, check sums and synchronization words. These are transmitted at 488 baud along with navigation information when applicable. To minimize the loss of data, each sampling of the sensor data is transmitted twice in each frame every second. Up to three spare data channels are provided for special research type applications. The Mark II is powered with two 9 volt lithium batteries that are installed at the factory.

The sonde uses a capacitive pressure capsule, a fast response miniature rod thermistor, and a carbon humidity element. All sensors are installed at the factory. The sonde is provided with an internal balloon train/navaid antenna combination with associated dereeling governor. A three stage highly stable tunable transmitter having an output of 250 mW and operating between 400-406 MHz serves to transmit the data stream to the ground data processing equipment. Sonde preparation is minimal, amounting to turning power on with an internal switch and tying the train/antenna to the balloon.

5.4 Receiving Antennas

Transmissions at 400-406 MHz are received on either a vertically polarized directional Yagi array (long range) or a circularly polarized quadrafile for hemispheric coverage (overhead). Switching between antennas is accomplished manually from the computer keyboard using a display of position and signal strength for the cue as to the most appropriate time to make the switch.

Transmissions at 1680 MHz are received on the radiotheodolite dish and down converted to 403 MHz at the dish.

5.5 Telemetry Receiver

After amplification at the antenna, telemetry signals are carried by coaxial cable to a dual conversion synthesized UHF receiver located in the Eurorack. All control functions of the receiver are executed from the computer keyboard via one of the two RS-232 communication channels. This concept permits extensive capability to be realized in a simple manner. For example, the serial number of the sonde being flown is programmed into the receiver at launch and the receiver will lock-on and track this sonde only until commanded otherwise; the receiver can perform a spectral analysis of the 400-406 MHz band prior to launch to check for interference.

The same receiver is employed for processing the down-converted 1680 MHz telemetry signals.

5.6 Navaid Systems

When navaids are used for wind determination, the detected navaid information is filtered and amplified and passed to a newly designed tracking module. (Beukers, Poppe 1987). This tracker is capable of Loran-C single and multiple chain operation. It will also synchronize to and track Omega and multiple VLF transmissions. A new state-of-the-art VLF synthesized receiver has been designed for the reception of Omega and VLF communication stations.

5.7 The P90 Bus

All modules are plugged into what has been called the P90 bus. This enables data and control signals to pass to and from modules on a common bus through one interface. Adhering to the concept of open architecture, full details of the bus with connections and signal specifications are provided. This permits a user to design special purpose modules and to have direct access to the system computer.

5.8 System Computer

The selection of an industry standard MS-DOS computer without modification allows customers to purchase their own in-country manufactured equipment. The only requirement is that the internal

BIOS and hardware complement meet the published W-9000 system specifications. There are significant service advantages to this method of procurement in addition to avoiding duty and overcoming import restrictions.

5.9 Application Software

All software is modular and written in high level language. In conformance with the policy of OA, listings and algorithms are made available to those users who wish to understand or modify the modules. If user changes are contemplated, an arrangement is made to address version control and revision responsibility.

6. OPERATIONAL COSTS

Having given a brief description of the system, we can return to the subject of equipment cost and on going operational expenditures. The basic system architecture was designed so that the system can be operated remotely by using a modem at the station and a second modem at a remote location. By this means, and by using one of the several commercially available software communication packages, the station can be operated and serviced over standard communication channels such as satellites or telephone lines. There are significant cost advantages to be realized with this approach.

6.1 Service

Communication via modem to the station computer and into the Eurorack effectively places a remote terminal into the system. This enables the system to be operated by service personnel from a central office and perform fault diagnosis and analyze data abnormalities should they occur. It also enables VIZ service personnel direct access to the system without the need to travel to the station location. Once diagnosed, the modular construction of the W-9000 permits easy and rapid exchange of a defective plug in module. The remote operation capability avoids the need for travel, significantly reduces the cost of service and minimizes station down time.

6.2 Software Maintenance and Upgrades

All signal processing modules are equipped with their own individual microprocessors. Software for these micros is resident in Electrically Erasable Programmable Random Access Memory (EEPROM) which can be accessed via the P90 bus. This feature offers the advantage that all software for the system can be downloaded via modem from VIZ's (or a central stations's) library of software modules. It is no longer necessary to provide firmware PROM's or diskettes, thereby simplifying and reducing the cost of software maintenance, upgrades and revisions. Travel, service time and shipping costs are minimized.

6.3 On-Line Help

It has been VIZ's experience that costly training of potential operators and maintenance personnel is often wasted because of personnel reassignments soon after the training has been completed. To minimize the costs associated with sending personnel to the factory for training and travel by VIZ personnel to user installations, an on line-help feature has been incorporated into the system operation. By depressing the F1 function key on the computer keyboard, information relating to the current operation is immediately available to the operator. The on-line help feature, in conjunction with operational simplicity of the W-9000 system, reduces the training requirement to keyboard familiarization. This is aided by a keyboard escutcheon which provides details of the most used commands.

6.4 License to Manufacture Locally

Design of the Mark II MICROSONDE has addressed the need for licensed manufacture. This subject has been covered in detail in a paper given by the author at the TECEMO conference in the Netherlands in 1984. The modular construction of the sonde permits manufacture and assembly with the minimum of capital equipment. The sensors and "Application Specific Integrated Circuits" that require a substantial investment to manufacture can be supplied by VIZ to a local manufacturer for assembly into locally manufactured parts. This method of manufacture reduces cost and is particularly important for those countries that find themselves without a surplus of hard currency. Licensed manufacture also reduces shipping costs, taxes and customs charges.

6.5 Co-Location of Equipment

When navaid systems are employed, the total equipment complement is little more than that now commonly found on an office desk. The small size, automated processing and the limited skills required to perform a sounding make the co-location of the sounding station with other operations a reality. This has the potential of saving a significant portion of the operational budget. Making use of institutes of learning or other existing facilities together with the available resident labor has the potential of reducing the cost of a sounding even further.

7. CONCLUSIONS

7.1 Improved Sondes

Radiosonde intercomparisons reveal that there is room for improvement in radiosonde accuracy. The burden is on the manufacturer to make these improvements at a time when there is a downward pressure on margins and volume. There is a need for cooperation with the user community to work towards both increased volume and additional funding appropriations.

7.2 Fragility of the Radiosonde Source of Supply

Static or shrinking markets and narrow margins make radiosonde manufacture unattractive for new entrants. It is unlikely that there will be any additions to the small number of existing manufacturers because of the large investment that has to be made with a low probability of an adequate return. Current manufacturers must be considered as a global asset until alternative means for atmospeheric sounding are operational and proven.

7.3 Achievable Economies

With the economies described for station operation, the purchase of locally manufactured equipment, service by electronic communication; and licensed manufacture of sondes, it is suggested that there can be a revitalization of the global sounding program. It is further suggested that this can be done while preserving the integrity and profitability of the suppliers This would appear to be timely on the basis of the premises laid out in the introduction to this paper.

7.4 Open Architecture

The design approach taken with the equipment and sonde described in this paper will prove to be a useful contribution to solving the problem of inadequate data from many areas of the globe.

8. REFERENCES

Beukers, John M., Poppe, Martin C. Jr., 1987: A Versatile Tracking Module with Loran-C Cross Chain Capability. Sixteenth Annual Meeting of the Wild Goose Association, Rockville Maryland, October.

Beukers, John M., 1984: Economics of Upper Air Soundings. TECEMO, Netherlands September.

SESSION 2: Quality of radiosonde data inferred from operational data monitoring at major data processing centres (Chairman: F. Finger))