6. DESIGN CONSIDERATIONS FOR HIGH-POWER VHF RADAR TRANSCEIVERS (Keynote Paper)

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The importance of the MST radar technique has been clearly established by the more than ten facilities presently operating in the clear-air radar mode. Some of the facilities such as Poker Flat and SOUSY were designed specifically as MST radars. Other facilities such as Arecibo and Millstone were designed for other applications, but are capable of being operated in the MST radar mode. Now that the MST technique has been demonstrated, many new groups are setting out to establish facilities. Some of the new groups are clearly research oriented, while others are applications oriented.

The facilities already established and operating in the MST mode have developed all of the equipment required for an MST radar. Because development of the electronic building blocks has already been accomplished, new research facilities can concentrate their efforts on engineering enhancements rather than "reinventing the wheel". Research facilities are now able to begin scientific work much sooner since much of the required electronics is commercially available. Applications oriented facilities are now feasible without lengthly design and development efforts.

Topic 6 -- "Design considerations for high-power VHF radar transceivers" provides an opportunity for the pioneers in the MST radar field to exchange status reports and results of the previous and current hardware developments. Topic 6 also provides an opportunity for those currently beginning to establish facilities to learn what has been done in the way of hardware development and integrate this information into their plans. In addition, Topic 6 provides a forum for discussion on the future directions of VHF radar transceiver development.

The subtopics to be discussed in Topic 6 include, (1) distributed versus single transmitters, (2) coded pulses and decoder design, (3) large transmitter design considerations, and (4) T/R switch design. A number of papers on each subtopic has been submitted and they will provide a reference point for the current status of engineering development. In addition the papers will provide a departure point for the discussion on future directions in transceiver development.

The topics to be included in the discussion on future directions will include the following, (1) enhanced receiver performance, (2) transmitter systems for unattended operation, (3) limitations of the current T/R switch designs, (4) data processing (is eight bits enough), and (5) new frequencies (200 MHz and/or 400 MHz).

Enhanced receiver performance will include discussions on the optimum noise figure versus dynamic range tradeoffs, the usefullness of fast attenuators (< 5 microsecond switching time) to increase dynamic range, and the requirements for bandwidth filtering.

Transmitter systems for unattended operation will include discussions on the control and monitoring systems, the optimum power level to maximize performance versus cost, and reliability versus cost tradeoffs.

Limitations of the current T/R switch designs discussion topic will include isolation limitations, and recovery time limitations.

Data processing will include discussions on 8-bit versus 10- or 12-bit A/D converters, preprocessor (preintegrator) requirements, and recent developments in the computer industry that can provide enhanced performance at a greatly reduced cost.

New frequencies discussions will include the advantages of higher frequencies, the cost tradeoffs of 50 MHz versus 200 MHz versus 400 MHz, the increase in resolution with higher frequencies, the lowering of the minimum height limitations, and the availability of various frequency allocations.

Hopefully during this session of the Workshop on Technical Aspects of MST Radar the current state of the art of high-power VHF radar transceivers will be defined, and the engineering development goals for the next year or two will be established.

SUMMARY AND RECOMMENDATIONS

The session on Topic 6 -- "Design Considerations for High Power VHF Radar Transceivers" was a detailed discussion on hardware design. The question of distributed transmitters versus a single large transmitter was studied. The two categories were expanded to three categories to include small, medium, and large transmitters. The small transmitters are characterized by power outputs of less than 10 kW peak power, such as the MU radar modules. The medium-sized transmitters have outputs in the range of 10 kW to 200 kW, such as the transmitters at the Poker Flat facility. The large transmitters provide outputs in excess of 200 kW, such as the transmitters at Jicamarca.

An MST radar based on small transmitters, such as the MU radar, appears to cost more per watt than a radar utilizing medium or large transmitters. Using small transmitters allows the system to be steered in many directions quite easily. The cost of small transmitters can only be justified if the potential steering ability of a system of this type is fully implemented.

The cost per watt of transmitter systems consisting of an array of medium-sized transmitters versus a single large transmitter appears to be about equal. The multiple transmitter approach utilizes smaller, more readily available components and has the advantage that a single transmitter failure does not make the entire system inoperative. A single large transmitter requires essentially 100 percent spares to allow continuous operation. In addition, the parts for a large transmitter are more difficult to obtain, with lead times on components such as high power capacitors running six months or more.

There was lively discussion on the optimum size of transmitters, with no clear conclusions reached. The engineering decisions should be based on the particular scientific and operational requirements, availability of equipment (some of the proponents of large transmitters had obtained their equipment surplus), and the type of technical support available for operation and maintenance.

T/R switch discussion centered on the importance of recovery time in order to obtain data from lower altitudes. Switching time is limited by the time constants of the components required for operation at 50 MHz. Present state of the art is about 1-km height for the first data; though this can probably be lowered somewhat with a few tricks, such as adding shorted quarter-wave transmission line stubs on the antenna feedlines, and lowering the Q of the RF chokes that isolate the PIN diodes from their driver circuitry.

There are many valid approaches to receiver design. The important requirements are dynamic range, rejection of interference, and sensitivity. With currently available components, it is relatively easy to approach an optimum design for sensitivity and interference rejection. Discussion centered around the dynamic range requirement and it was determined that the limiting factor in systems with an 8-bit A/D converter was the dynamic range of the converter itself. A minimum of 10 bits in the A/D converter is recommended for all future systems, in order to take advantage of the dynamic range capability in a well-designed receiver.

Explored in a limited fashion during this session were the transmitter requirements for systems operating at higher frequencies such as 200 MHz and 400 MHz. Lumped components are still suitable at 200 MHz and possibly at 400 MHz, while cavities are probably more efficient, though more costly, at 400 MHz. Higher frequency operation is being considered to enable faster T/R switch recovery for lowering the minimum altitude at which data can be obtained and for reducing the size of the antennas so that portable systems may be built. It was generally felt that systems at the higher frequencies would not cost significantly more than systems at 50 MHz and that efforts should be made to develop transmitters at the higher frequencies as dictated by the scientific requirements.

RECOMMENDATIONS

1) Transmitter designs for operation at higher frequencies such as 200 MHz and 400 MHz should be investigated for use as portable ST systems and for faster recovery times for lowering the minimum altitude capabilities of MST systems.

2) A/D converters with a minimum of 10-bit resolution should be utilized in all future radar systems to optimize the dynamic range capabilities of new MST radars.