P1.17 COMMERCIAL SIMULTANEOUS DUAL POLARIZATION RADAR

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1. INTRODUCTION

The majority of weather radar systems in operation today are of the single polarization variety. Liquid hydrometeors, being somewhat oblong as they fall through the atmosphere, give a slightly stronger horizontal return, hence these radar systems are horizontally polarized. The singly polarized radar systems have severe limitations in regions with partial beam blockage and with hydrometeor classification.

To overcome these shortcomings of singly polarized weather radar systems, systems with alternating pulses of horizontally and vertically polarized signals have been implemented. These systems allowed classification schemes through the inference of hydrometeor shape (Ryzhkov (1999a), Ryzhkov (1999b), Liu (1999), Vivekanandan (1999), and Zrnic (1999)). In addition, by looking at phase differences between the horizontal and vertical components the effects of partial beam blockage can be mitigated and greater clutter rejection can be obtained (Ryzhkov (2000)). However, the underlying assumption is that subsequent pulses (those of each polarization) are highly correlated (an extremely slow moving antenna) and the effective velocity range is reduced by a factor of two.

The next natural evolutionary step for weather radar systems is to move from the transmission and reception of alternating polarization modes to simultaneous polarization modes. This paper addresses some of the issues that need to be analyzed by the end user in concert with the manufacturer to ensure optimum configuration of a simultaneous dual polarization system.

2. ALTERNATING DUAL POLARIZATION

Current dual polarization weather radar systems switch between polarization modes on a pulse by pulse basis. A representative system is diagrammed in Figure 1. To switch the polarization modes, a high power, high speed waveguide switch to transfer the transmitted energy between a horizontally oriented waveguide and a vertically oriented waveguide.

A primary issue surrounding alternating dual polarization systems is the required high power switch. These switches are specialized pieces of equipment and thus tend to be very expensive and difficult to maintain. In addition they tend to have relatively low isolation between the two modes. In the ten years of fielding these high power, dual

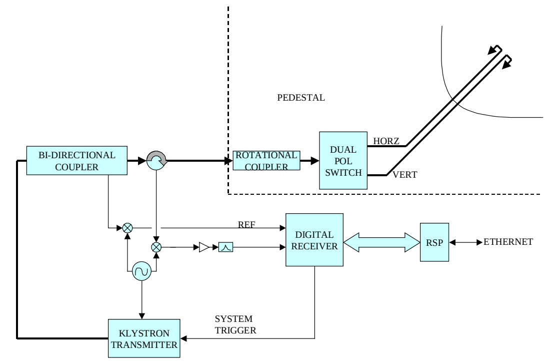

Figure 1. Block diagram of representative alternating Dual polarization radar system. The Dual Pol Switch switches between the Horizontal (Hor) and Vertical (Vert) ports on a pulse by pulse basis. A single receiver is used to process the detected signals.

polarization switches, we have found the reliability to be somewhat dependent upon the transmission frequency.

The dual polarization switch is a ferrite phase shifter. The operation of the switch is via establishing the magnetic field in the ferrite core before the transmission of the pulse. The coupling of the magnetic field and the electromagnetic pulse causes Faraday rotation, i.e. rotation of the plane of polarization as the pulse passes through the ferrite medium. Through this process, the energy from the pulse is directed to one of two output ports, a horizontally oriented port and a vertically oriented port.

The size of the ferrite core is highly dependent upon the wavelength and hence frequency of the radar system. The longer the wavelength, the larger the ferrite core and the greater the doped surface area which will absorb microwave energy. We believe the high rate of S-band switch failures were due to the changes in crystalline structure of the ferrite material

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resulting from the increased energy absorption. At higher frequencies, C and X band, we have experienced very few failure issues and therefore enjoyed great success.

Other organizations have implemented mechanical rather than electromagnetic switches in S-band systems. However, mechanical switches are also not without their problems.

3. SIMULTANEOUS DUAL POLARIZATION

The evolution of dual polarization weather radar systems from an alternating polarization mode to a simultaneous dual polarization mode will solve the issues of long dwell times, velocity range reduction, and eliminate the expensive and hard to maintain dual polarization switch.

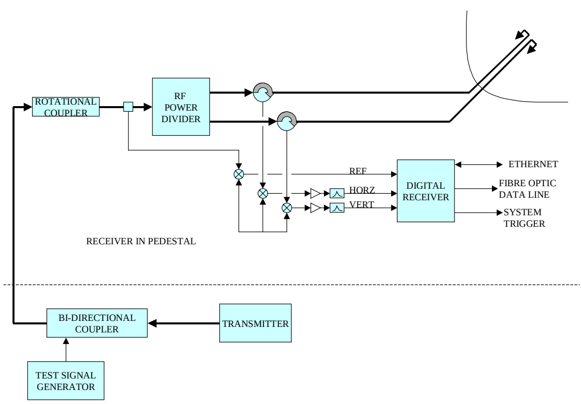

Figure 2. Block diagram of representative simultaneous dual polarization radar system. A power divider splits the transmitted energy into components that are transmitted to each of the polarization feed horns. Two receivers are utilized, one for each polarization mode.

Figure 2 is a basic block diagram representation of an inexpensive solution to the simultaneous dual polarization requirements. Comparing Figure 2 to Figure 1 clearly shows the replacement of the dual polarization switch by a power divider (Doviak (2000)). Additionally, a second circulator and receiver has been added. The second receiver can be an entire second receiver system, or a second channel of a multichannel receiver system. Similarly, depending upon the associated applications, the requisite signal processor may be separate signal processors with the data integrated by a communications processor, or a single signal processor board with facilities and computing power to perform all the necessary processing. The latter implementation for the receiver and the signal processor is simpler, easier to maintain, and hence more desirable.

The primary disadvantage of this solution is the division of transmit power. An operator wanting to transmit and analyze data in a single polarization mode at 500 KW will require a 1 MW transmitter. A simple solution to this issue is a mechanical transfer switch designed into the waveguide structure to bypass the power divider. Thus, full transmit power can be achieved in a single polarization mode.

There are several configurations which, when implemented, will satisfy the based system diagrammed in Figure 2. We have chosen to a "receiver over elevation" configuration as shown in Figure 3 for its high performance to cost ratio.

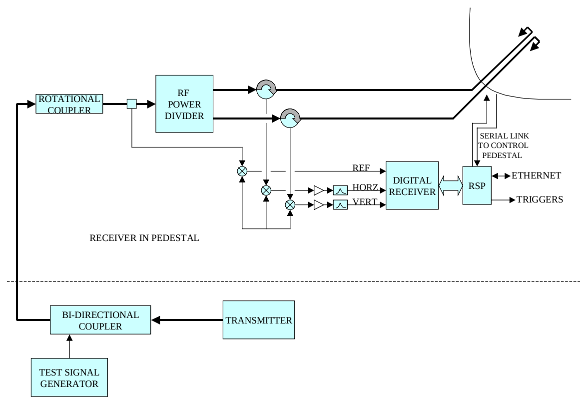

Figure 3. Block diagram of for the receiver over elevation simultaneous dual polarization system. The receiver and signal processor(s) are located in an environmentally controlled enclosure located above the elevation rotary coupler.

The "receiver over elevation" configuration places the receivers above the elevation rotary coupler, minimizing the necessary channels of waveguide. Dual channel rotary couplers are expensive and introduce phase errors between the channels that vary with rotation. Placing the receivers above the elevation coupler facilitates the use of single channel rotary couplers for both the azimuthal and elevation axes.

The receiver over elevation configuration places the receivers very close, physically, to the antenna. If the signal processor were physically located near the transmitter or workstation, data transmission from the receivers to the signal processors could be a problem. Complex and expensive slip ring would be required to transmit the data. However, technology has evolved to where it is practical to place the signal processor(s) together with the receiver at the antenna and just transmit the resultant data moments to the workstation. This simplifies the slip ring assembly, requiring only paths for power, reference, Ethernet communications, and motor drives.

The active electronics, receiver and signal processor, are located in a small enclosure. This enclosure is environmentally controlled via solid state heating and cooling unit.

For magnetron based radar systems, the receiver measures the phase-frequency relationship on a pulse basis. The burst sample is obtained prior to the RF Power divider and transmitted via a coupler to the receiver for processing. This technique yields the highest possible coherency, approaching the theoretical limit for magnetron systems.

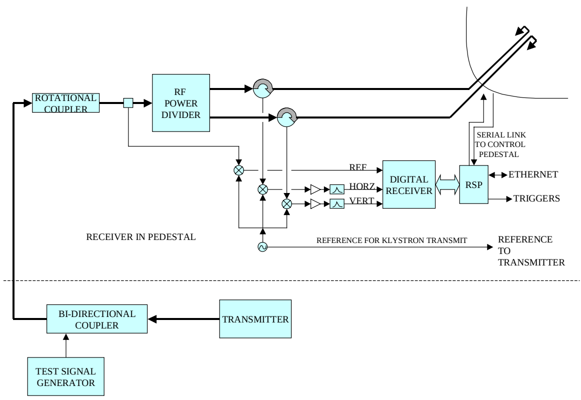

Figure 4. Block diagram of for the receiver over elevation simultaneous dual polarization system. The receiver and signal processor(s) are located in an environmentally controlled enclosure located above the elevation rotary coupler.

For Klystron based radar systems (Figure 4), the local oscillator is located at the receiver and a timing reference signal is used to phase lock to the master synthesizer located at the transmitter. Similar to the magnetron system, the actual transmitted burst is sampled and processed by the receiver. Therefore, compensation for the phase shift introduced by the amplification process is automatic. Again this process yields high coherency values.

4. CONCLUSION

Current dual polarization weather radar systems alternate polarization mode on a pulse by pulse basis through the use of high power, high speed dual polarization switches. The next generation of dual polarization weather radars will eliminate the switch, transmitting and receiving in both horizontal and vertical modes simultaneously.

The transition from alternating dual polarization to simultaneous dual polarization eliminates the current issues with long dwell times and velocity range reduction. In addition, the elimination of the expensive and difficult to maintain high power polarization switch.

The benefits of simultaneous dual polarization systems are substantial. They provide much more information, allowing for the determination of the entire scattering matrix, correction for partial beam blockage via differential phase techniques, improved rainfall estimates, and improved hydrometeor classification.

5. REFERENCES

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