Analysis and Implementation of Polarization Schemes for Polarimetric Radar Systems

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Abstract. *Polarization schemes recently employed in atmospheric radar systems are described and compared. The considered polarization schemes are: the switching polarization scheme, the hybrid polarization scheme, and the extended hybrid polarization scheme. Performance of polarimetric radar systems using each of these schemes is simulated. These simulations provide insight into strengths and weaknesses of each scheme, and as such, provide a way of choosing the right one for a particular radar application. Results show that the widely accepted hybrid polarization scheme suffers from significant mutual coupling of the measurable values. Depending on the application, the switching or extended hybrid scheme proves to be better choice.*

Keywords

Weather radar, polarimetric radar, switching polarization scheme, hybrid polarization scheme, extended hybrid polarization scheme.

1. Introduction

Weather radars provide valuable data for studying of the atmosphere, clouds, storms, precipitation and other meteorological phenomena [1]. Implementation of multi-polarization and multi-frequency measurements allow not only the detection of volume targets in the atmosphere, but also of getting information on target composition and density, hydrometeor shape, etc. [2 – 5].

Most weather radars transmit pulses of a single polarization. Polarimetric radars, on the other hand, transmit pulses that have both horizontal and vertical polarizations (Fig. 1) [3], [6]. The polarization scheme used by the radar affects how a radar system "sees" the environment. The radar image obtained using different polarization combinations may provide different and complementary data, giving the user more information regarding the observed object.

The horizontally polarized pulses essentially give a measure of the horizontally oriented scatterer of a cloud or precipitation particles. The vertically polarized pulses give a measure of their vertical properties. The power returned to the radar is a function of each particle's size, shape and density. This additional information results in improved estimates of rain and snow rates, better detection of large hail location in summer storms, and improved identification of rain/snow transition regions in winter storms [2–5].

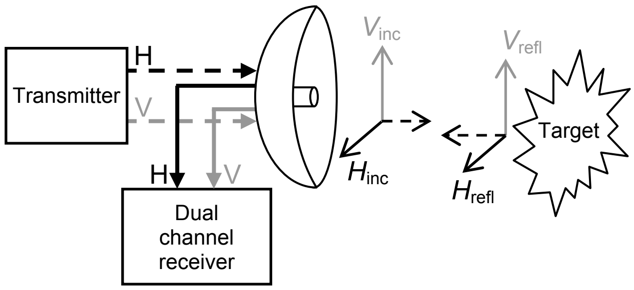


Fig. 1. Concept of a polarimetric radar.

An antenna capable of transmitting and receiving two orthogonal polarizations with substantial isolation between the two is critically important in polarimetric radar system. The signal path from transmitter to the antenna ports and the method by which the received signal is processed establishes the polarization scheme and the difference between various polarimetric radar types.

Currently, polarimetric radar systems employ one of three polarization schemes; the switching polarization scheme, the hybrid polarization scheme [7], and the extended hybrid polarization scheme. The switching polarization scheme was first one to be widely adopted in spite of complex hardware requirements. This polarization scheme is now being replaced by the simpler hybrid polarization scheme. However, the hybrid polarization scheme introduces new problems [2]. To keep the advantages of the hybrid polarization scheme and at the same time solve its drawbacks the extended hybrid polarization scheme has been developed. The analysis of these three schemes is presented in this paper.

2. Polarimetry

The polarimetric properties of a target can be represented by its scattering matrix

$$[\mathbf{S}] = \begin{bmatrix} s_{hh} & s_{hv} \\ s_{vh} & s_{vv} \end{bmatrix}. \tag{1}$$

In (1) it is assumed that the radar employs linear orthogonal polarizations (horizontal and vertical, indices *h* and *v*). Elements on the main diagonal are obtained by co-polarized measurement (polarizations of the transmitted and received pulse are the same). Elements off the main diagonal are obtained by cross-polarized measurement (polarization of the transmitted and received pulse are orthogonal, say H and V). Due to reciprocity, it is usually assumed that the parameters s_{hv} and s_{vh} are of the same value.

The ultimate goal of polarimetric measurements is to obtain values of the elements in the scattering matrix. The radar usually operates at a certain distance from the target, which means there will be some influence of the propagation media involved. The scattering matrix of the target is used to relate transmitted and received electric field vectors as follows:

$$\begin{bmatrix} E_h \\ E_v \end{bmatrix}^{Rx} = \begin{bmatrix} T_h & 0 \\ 0 & T_v \end{bmatrix} \begin{bmatrix} s_{hh} & s_{hv} \\ s_{vh} & s_{vv} \end{bmatrix} \begin{bmatrix} T_h & 0 \\ 0 & T_v \end{bmatrix} \begin{bmatrix} E_h \\ E_v \end{bmatrix}^{Tx}, \tag{2}$$

$$T_h = \sqrt{\Delta A_h} \exp\left(-j\frac{\varphi_{DP}}{2}\right), \tag{3}$$

$$T_v = \sqrt{\Delta A_v} \tag{4}$$

where (3) and (4) describe elements of the transmission matrix. The effects of the propagation media are taken into account through horizontal attenuation ΔA_h, vertical attenuation ΔA_v and round trip differential phase φ_{DP}.

The radar echo carries signatures of both target and propagation media. Different polarization schemes have different capabilities (and different ways) to extract particular measurable parameter.

The matrix equation (2) can be decomposed into

$$E_h^{Rx} = E_h^{Tx} T_h^2 s_{hh} + E_v^{Tx} T_h T_v s_{hv} \tag{5}$$

and

$$E_v^{Rx} = E_v^{Tx} T_v^2 s_{vv} + E_h^{Tx} T_h T_v s_{vh}. \tag{6}$$

Polarimetric radars are usually equipped with a dual channel receiver (Fig. 1). One channel of the receiver is connected to the horizontal polarization port of the antenna and the other one to the vertical polarization port of the antenna. The horizontal channel of the receiver will then produce result described by (5) and the vertical channel result described by (6).

3. Polarization Schemes

3.1 Switching Polarization Scheme

The switching polarization scheme is used in most polarimetric weather radar systems today. The radar antenna is designed for transmission and reception of at least two polarizations, usually horizontal and vertical, and employs fast microwave switch to direct the signal from the transmitter to either the horizontal or vertical port of the antenna.

Polarimetric measurements are usually done in two steps. First, the radar transmits horizontally polarized signal. The radar then receives the target echo in two channels: horizontal and vertical. The signal in the horizontal channel is called co-polarized (Co-pol, eq. (5)), since it has the same polarization as the transmitted pulse. The signal in the vertical channel is called cross-polarized (X-pol, eq. (6)), due to the fact that this one is orthogonally polarized with respect to the transmitted pulse. If the transmitted pulse is horizontally polarized, right hand sides of (5) and (6) can be converted from electric field strengths into voltages using

$$H_{Co-Pol} = G_H^{Rx} E_h^{Rx} = G_H^{Rx} E_h^{Tx} T_h^2 s_{hh}, \tag{7}$$

$$H_{X-Pol} = G_V^{Rx} E_v^{Rx} = G_V^{Rx} E_h^{Tx} T_h T_v s_{vh}, \tag{8}$$

where G_H^{Rx} and G_V^{Rx} are constants for the horizontal and vertical channel of the receiver, respectively. Using these values, it is possible to determine the horizontal reflectivity Z_h as

$$Z_h = C_{RH} \left\langle \left| H_{Co-Pol} \right|^2 \right\rangle \tag{9}$$

and linear depolarization ratio (horizontally polarized pulse transmitted), LDR_{vh}

$$LDR_{\mathrm{vh}} = 10 \log\left(\frac{\left\langle \left| H_{\mathrm{X-Pol}} \right|^2 \right\rangle}{\left\langle \left| H_{\mathrm{Co-Pol}} \right|^2 \right\rangle} \right), \tag{10}$$

where C_{RH} is a calibration constant for the whole horizontal radar subsystem. This constant is determined by the external radar calibration. Values given by (9) and (10) are radar measurables. These measurables give some information about certain elements of the target's scattering matrix. Ideally, it can be stated:

$$\left\langle \left| H_{\mathrm{Co-Pol}} \right|^2 \right\rangle \propto \left\langle \left| s_{\mathrm{hh}} \right|^2 \right\rangle \tag{11}$$

and

$$\frac{\left\langle \left| H_{\mathrm{X-Pol}} \right|^2 \right\rangle}{\left\langle \left| H_{\mathrm{Co-Pol}} \right|^2 \right\rangle} = \frac{\left\langle \left| s_{\mathrm{hv}} \right|^2 \right\rangle}{\left\langle \left| s_{\mathrm{hh}} \right|^2 \right\rangle}. \tag{12}$$

Vertically polarized transmission is treated similarly. Now the signal in horizontal channel is orthogonally polarized with respect to the transmitted signal (X-pol) and the signal in vertical channel is co-polarized one. The respective voltages are:

$$V_{X-Pol} = G_H^{Rx} E_h^{Rx} = G_H^{Rx} E_v^{Tx} T_h T_v s_{hv}, \tag{13}$$

$$V_{Co-Pol} = G_V^{Rx} E_v^{Rx} = G_V^{Rx} E_v^{Tx} T_v^2 s_{vv}. \tag{14}$$

Using these newly measured values it is possible to obtain vertical reflectivity Z_v as

$$Z_v = C_{RV}\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle \tag{15}$$

and linear depolarization ratio (vertically polarized pulse transmitted), LDR_{hv}

$$LDR_{hv} = 10 \log\left(\frac{\left\langle \left| V_{X-Pol} \right|^2 \right\rangle}{\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle} \right) \tag{16}$$

where C_{RV} is a calibration constant for the vertical radar subsystem. As before, in ideal conditions it can be stated:

$$\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle \propto \left\langle \left| s_{vv} \right|^2 \right\rangle \tag{17}$$

and

$$\frac{\left\langle \left| V_{X-Pol} \right|^2 \right\rangle}{\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle} = \frac{\left\langle \left| s_{vh} \right|^2 \right\rangle}{\left\langle \left| s_{vv} \right|^2 \right\rangle}. \tag{18}$$

Due to reciprocity, LDR_{vh} and LDR_{hv} are of equal value.

After horizontally and vertically polarized pulse have been transmitted, it is possible to calculate remaining polarimetric values. Differential reflectivity, Z_{DR}, is defined as:

$$Z_{DR} = 10 \log\left(\frac{\left\langle \left| H_{Co-Pol} \right|^2 \right\rangle}{\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle} \right). \tag{19}$$

Differential phase φ_{DP} is given by

$$\varphi_{DP} = \mathrm{Arg}\left\langle H_{Co-Pol}{}^{*} \cdot V_{Co-Pol} \right\rangle, \tag{20}$$

and specific differential phase, K_{DP} is obtained from

$$K_{DP} = \frac{\partial}{\partial R}\left\{ \varphi_{DP} \right\}. \tag{21}$$

One remaining polarimetric measurable is correlation coefficient with zero lag, $\rho_{hv}(0)$. However, since the measurements are completed with two pulses, the best that can be done is correlation coefficient with time lag of one pulse, $\rho_{hv}(T_S)$ defined as:

$$\rho_{hv}(T_S) = \frac{\left\langle V_{Co-Pol} \cdot H_{Co-Pol}{}^{*} \right\rangle}{\sqrt{\left\langle \left| V_{Co-Pol} \right|^2 \right\rangle}\sqrt{\left\langle \left| H_{Co-Pol} \right|^2 \right\rangle}}. \tag{22}$$

The switching polarization scheme is relatively simple to use. There is no unwanted interaction between propagation media properties and target depolarization. This is achieved because radar transmits either horizontally or vertically polarized pulse, not both at the same time. Full polarimetric measurement requires at least two pulses, although many more pulses are used and the result is averaged.

One of the challenging hardware issues in polarimetric radar systems employing switching polarization scheme is the implementation of the high power microwave switch. Latching circulators are commonly used microwave components for this purpose. Only in very high peak power (hundreds of kW) applications this implementation is not feasible. In this case the switching polarization scheme is implemented with two transmitters. Each of these transmitters is dedicated to one polarization (H and V transmitters). However, this tends to be an expensive solution.

Another problem that the switching polarization scheme suffers from has purely meteorological background. Namely, linear polarization (H or V) is sensitive to both, orientation and the shape of the hydrometeors [1].

3.2 Hybrid Polarization Scheme

The hybrid polarization scheme has been adopted recently [2], [7], [8]. This polarization scheme uses circular polarization to decouple the sensitivity to shape and orientation of the hydrometeors. Furthermore, since the power from the transmitter is divided between H and V channels, there is no need for the high peak power switch. However, the price paid is a significant interaction between the properties of the propagation media and properties of the hydrometeors in the observation volume. The hybrid polarization scheme is particularly sensitive to the simultaneous presence of depolarizing targets and anisotropy of the medium resulting in differential phase, as can be seen from equations (5) and (6).

The hybrid polarization scheme is based on simultaneous transmission and simultaneous reception (STSR) of H and V polarizations [7]. The phase angle between H and V channels determines the actual transmitted polarization, which ranges from slanted ±45° linear polarization to left or right hand circular polarization. Slanted 45° linear polarization can be achieved using hardware setup shown in Fig. 2.

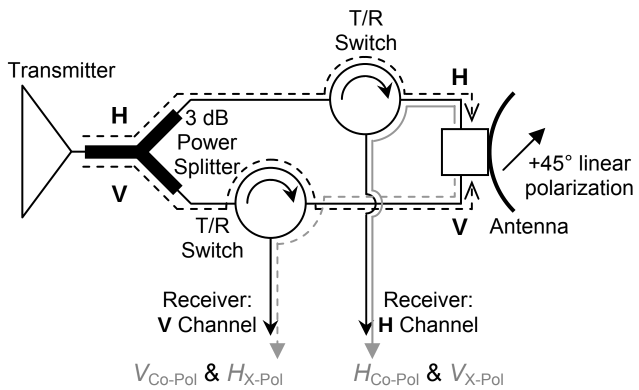
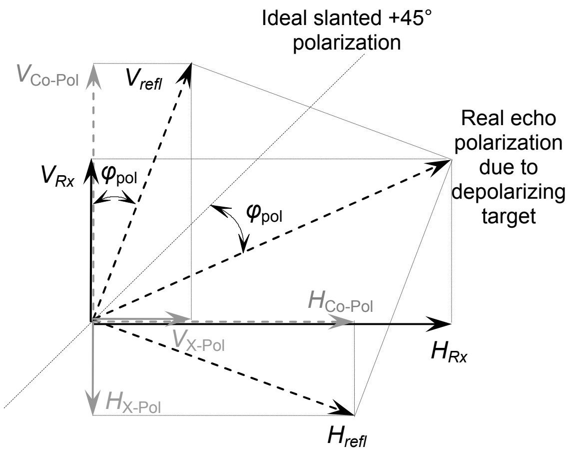


Fig. 2. Hybrid polarization scheme hardware implementation.

During transmission, the signal is divided into two paths: H and V. If the phase difference between the two channels is the same, the antenna will transmit perfect 45° slanted linearly polarized signal.

During reception, the polarimetric antenna will decompose the received signal into H and V components. Since both polarizations were transmitted simultaneously, both channels of the receiver will also simultaneously contain co-pol and cross-pol component of the signals (recall (5) and (6)). In the special case of non-depolarizing targets, both channels will contain only the co-polarized components. However, if the targets have depolarizing properties, both channels of the receiver will contain strong co-pol signal superimposed with (usually) much smaller cross-polarized components. A vector diagram for this situation is shown in Fig. 3.



Fig, 3. Effect of the depolarizing target on the hybrid polarization signal.

Fig. 3 illustrates how a depolarizing target ($s_{hv} \neq 0$) will rotate polarization plane for an angle φ_{pol}:

$$\varphi_{\text{pol}} = \arctan\left(\frac{V_{\text{X-Pol}}}{V_{\text{Co-Pol}}}\right) = \arctan\left(\frac{H_{\text{X-Pol}}}{H_{\text{Co-Pol}}}\right). \tag{23}$$

This time equations (5) and (6) can be rewritten in following form:

$$H_{Rx} = G_h^{Rx} E_h^{Rx} = G_h^{Rx}\left(E_h^{Tx} T_h^2 s_{hh} + E_v^{Tx} T_h T_v s_{hv}\right) \tag{24}$$

and

$$V_{Rx} = G_v^{Rx} E_v^{Rx} = G_v^{Rx}\left(E_v^{Tx} T_v^2 s_{vv} + E_h^{Tx} T_h T_v s_{vh}\right). \tag{25}$$

From (24) and (25) it can be seen that in this polarization scheme, each receiver channel will receive some combination of co-pol signal and cross-pol signal. This happens because the radar employing hybrid polarization scheme transmits pulses of both polarization at the same time (both E_h^{Tx} and E_v^{Tx} have nonzero values).

Polarimetric radar products are defined slightly differently for this polarization scheme. Horizontal reflectivity is proportional to the power in the horizontal channel of the receiver:

$$Z_{\text{h}} = C_{\text{RH}} \left\langle \left|H_{Rx}\right|^2 \right\rangle. \tag{26}$$

Vertical reflectivity is, similarly, proportional to the power in the vertical receiver channel:

$$Z_{\text{v}} = C_{\text{RV}} \left\langle \left|V_{Rx}\right|^2 \right\rangle. \tag{27}$$

Differential reflectivity is defined as the ratio of powers in the horizontal and vertical receiver channels:

$$Z_{\text{DR}} = 10 \log\left(\frac{\left\langle \left|H_{Rx}\right|^2 \right\rangle}{\left\langle \left|V_{Rx}\right|^2 \right\rangle}\right). \tag{28}$$

Differential phase can be obtained from

$$\varphi_{\text{DP}} = \text{Arg}\left\langle H_{Rx}^{\ *} \cdot V_{Rx} \right\rangle, \tag{29}$$

and specific differential phase from

$$K_{\text{DP}} = \frac{\partial}{\partial R}\left\{\varphi_{\text{DP}}\right\}. \tag{30}$$

Zero lag correlation coefficient can be obtained more directly with hybrid polarization scheme than it was a case for switching scheme, simply because there is no time lag between H and V pulses. The correlation coefficient is defined as

$$\rho_{\text{hv}}(0) = \frac{\left\langle V_{Rx} \cdot H_{Rx}^{\ *} \right\rangle}{\sqrt{\left\langle \left|V_{Rx}\right|^2 \right\rangle}\sqrt{\left\langle \left|H_{Rx}\right|^2 \right\rangle}}. \tag{31}$$

Analyzing definitions given in equations (26) to (31) but keeping in mind the receivers' voltage outputs given in (24) and (25) the following becomes obvious: these definitions of radar products will yield accurate results only if there are no depolarization effects. This is the major drawback of the hybrid polarization scheme.

Due to this effect, hybrid polarization scheme is considered in [8] as the method that does not allow depolarization ratio measurement. It is still possible to define the depolarization ratio for the hybrid polarization scheme, although its applicability is limited. Depolarization ratio is defined as

$$DR = 10 \log\left(\frac{\left\langle \left|H_{Rx} - V_{Rx}\right|^2 \right\rangle}{\left\langle \left|H_{Rx} + V_{Rx}\right|^2 \right\rangle}\right). \tag{32}$$

Recalling (24) and (25), it can be seen that in (32) the propagation media properties are mixed with the depolarization properties of the target in a way that cannot be resolved. This means the (32) will yield useful result (for example, *LDR*) only if:

1. phase difference between the H and V channels of the transmitter is zero,
2. differential phase in the propagation media is zero ($\varphi_{DP} = 0$),
3. co-pol returns are equal (which implies both, $Z_{DR} = 0$ dB and attenuations in H and V plane are equal).

As it can be seen, these are not so trivial limitations. Furthermore, only the first one is controllable by the radar designer.

Fig. 4 shows the signal phase relations at the outputs of the receiver channels. As it can be seen, only for $\varphi_{DP} = 0$ the phase relations are correct for obtaining *LDR* from equation (32). Any other angle will produce a result that can be called depolarization ratio, but it does not have clear meteorological application [8].

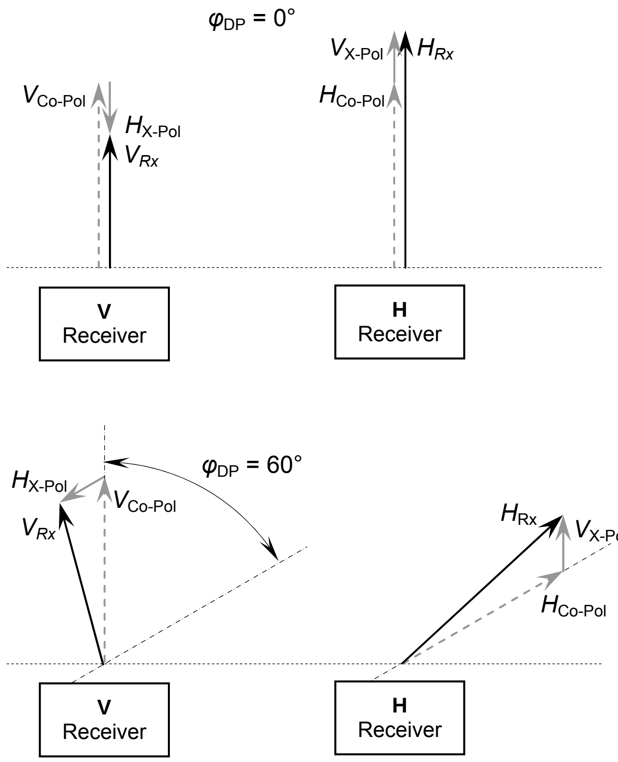


Fig. 4. Phase relations at the output of the receiver channels for two different φ_{DP} values (0° and 60°).

Introducing one more measurement can solve the problem of mixing the propagation media properties and the target properties. This is done in the extended hybrid polarization scheme.

3.3 Extended Hybrid Polarization Scheme

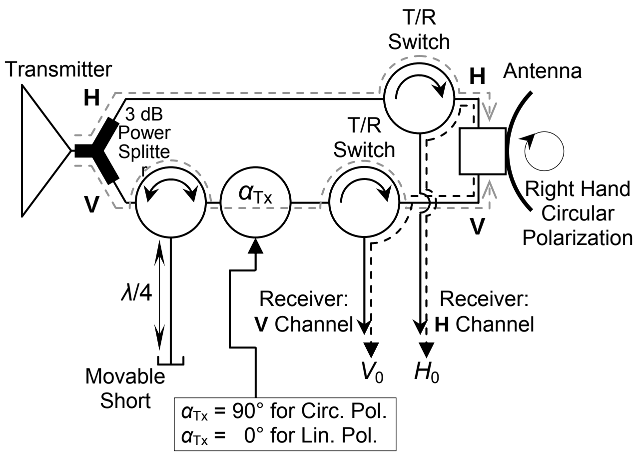


Fig. 5. The extended hybrid polarization scheme: transmission of RHCP pulse.

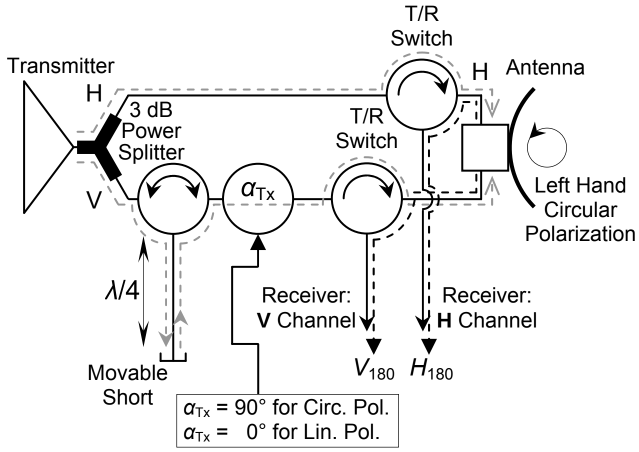


Fig. 6. The extended hybrid polarization scheme: transmission of LHCP pulse.

The hardware implementation of the extended polarization scheme is shown in Fig. 5 and 6.

The extended polarization scheme combines the advantages of both, switching scheme and hybrid polarization scheme. Circular or slanted linear polarization from hybrid polarization scheme is kept. In that way the meteorological advantage of not being sensitive to shape and orientation of hydrometeors is retained. The problem of mixing the propagation media properties with the target properties is solved by introduction of the measurement in which one channel of the transmitter is inverted. This additional measurement is needed in order to decouple propagation media properties from the target properties.

The hardware implementations of the extended and normal hybrid polarization scheme are almost the same. The implementation of the extended polarization scheme requires one more phase shifter. The function of this phase shifter is to insert additional phase shift of 180º in one of the transmitter channels (in case of Fig. 5 and 6 the vertical channel is chosen). This is done in alternating fashion: one pulse is transmitted without phase shift and the other one is inverted (phase shift of 180º). Depolarization due to the target properties will be the same in all pulses. However, the effect of the medium will be different from pulse to pulse. This difference is the key factor in decoupling the two.

In case of the extended hybrid polarization scheme (5) and (6) can be rewritten as

$$H_0 = G_h^{Rx}\left(E_h^{Tx}T_h^2 s_{hh} + E_v^{Tx}T_h T_v s_{hv}\right) \quad (33)$$

and

$$V_0 = G_v^{Rx}\left(E_v^{Tx}T_v^2 s_{vv} + E_h^{Tx}T_h T_v s_{vh}\right) \quad (34)$$

for the RHCP pulse transmitted, and

$$H_{180} = G_h^{Rx}\left(E_h^{Tx}T_h^2 s_{hh} - E_v^{Tx}T_h T_v s_{hv}\right) \quad (35)$$

and

$$V_{180} = G_v^{Rx}\left(-E_v^{Tx}T_v^2 s_{vv} + E_h^{Tx}T_h T_v s_{vh}\right) \quad (36)$$

for the LHCP pulse transmitted. The definitions of the radar products using the extended polarization scheme are then given as:

$$Z_h = C_H \left\langle \left| \frac{H_0 + H_{180}}{2} \right|^2 \right\rangle, \tag{37}$$

$$Z_v = C_V \left\langle \left| \frac{V_0 - V_{180}}{2} \right|^2 \right\rangle, \tag{38}$$

$$LDR_\Sigma = 10 \log \left(\frac{\left\langle \left| V_0 + V_{180} \right|^2 \right\rangle}{\left\langle \left| H_0 + H_{180} \right|^2 \right\rangle} \right), \tag{39}$$

$$LDR_\Delta = 10 \log \left(\frac{\left\langle \left| H_0 - H_{180} \right|^2 \right\rangle}{\left\langle \left| V_0 - V_{180} \right|^2 \right\rangle} \right), \tag{40}$$

$$Z_{DR} = 10 \log \left(\frac{\left\langle \left| H_0 + H_{180} \right|^2 \right\rangle}{\left\langle \left| V_0 - V_{180} \right|^2 \right\rangle} \right), \tag{41}$$

$$\rho_{hv}(T_S) = \frac{\left| \left\langle \left(\frac{H_0 + H_{180}}{2} \right) \left(\frac{V_0 - V_{180}}{2} \right)^* \right\rangle \right|}{\sqrt{\left\langle \left| \frac{H_0 + H_{180}}{2} \right|^2 \right\rangle} \sqrt{\left\langle \left| \frac{V_0 - V_{180}}{2} \right|^2 \right\rangle}}, \tag{42}$$

and

$$\varphi_{DP} = \mathrm{Arg} \left\langle \left(\frac{H_0 + H_{180}}{2} \right) \left(\frac{V_0 - V_{180}}{2} \right)^* \right\rangle. \tag{43}$$

Fig. 7 shows the phase relations in the system employing the extended hybrid polarization scheme. From these phasor representations it can be seen that, regardless of the differential phase angle introduced by the propagation medium, the sums and differences of measurable vectors will always give the desired result.

4. Analysis

Computer simulations of the described polarization schemes have been performed. Some of the results of these simulations are presented in Figs. 8 to 10. Fig. 8 shows simulated measurement results of the circular depolarization ratio (*CDR*) vs. the differential phase. As the linear depolarization ratio (*LDR*) is pure target property, four values of *LDR* were used as parameter. Results show that the radar system employing hybrid polarization scheme will have significant error in depolarization ratio measurement even if very small non-zero values of differential phase (i.e. phase difference between the V and H channels) are present. Under the same conditions the switching polarization scheme and the extended hybrid polarization scheme will both yield accurate results.

Fig. 9 shows the simulated measurement of the differential phase using the hybrid polarization scheme. As it can be seen, there is significant error in measurement caused by the depolarization of the target. The switching polarization scheme and the extended polarization scheme do not suffer from this disadvantage.

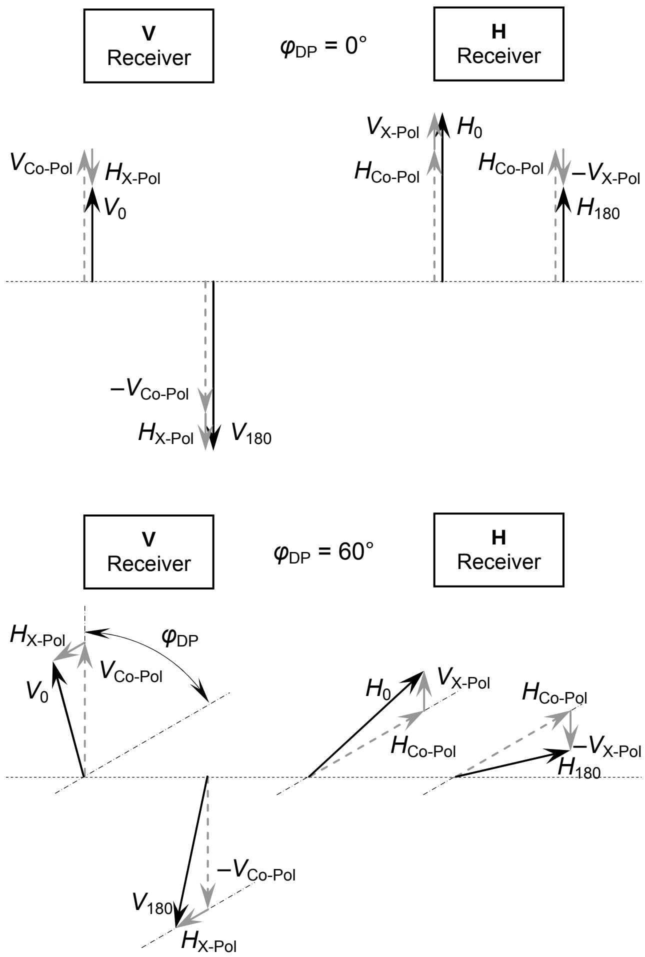


Fig. 7. Phase relations at the output of the receiver channels for two different φ_{DP} values (0° and 60°).

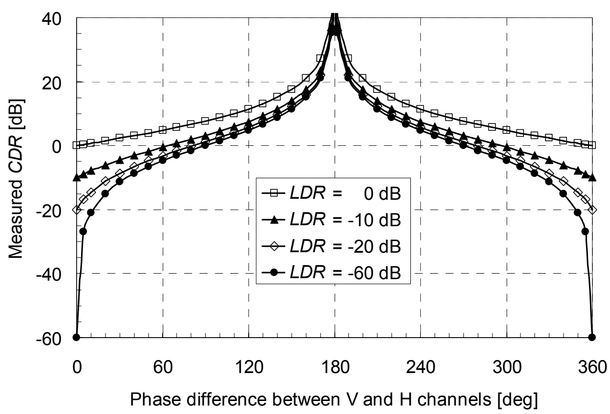


Fig. 8. Simulated measurement results of circular depolarization ratio (*CDR*) using the hybrid polarization scheme, according to (32). Ideally, the value of the *CDR* should correspond to *LDR* parameter: -60, -20, -10 and 0 dB for every value of phase difference. In hybrid polarization scheme, this is true only of for phase difference of 0°.

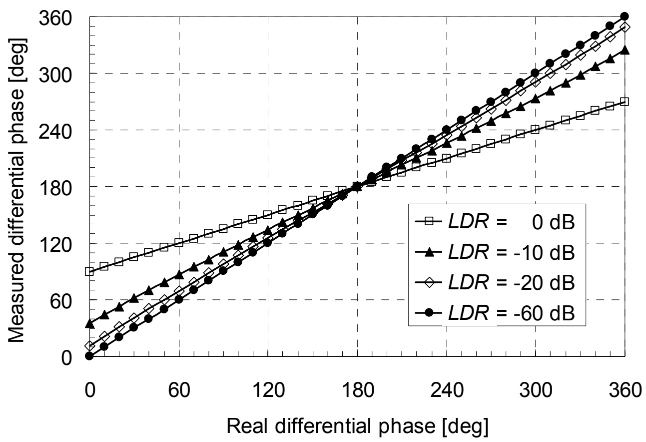


Fig. 9. Simulated measurement results of the differential phase using the hybrid polarization scheme, according to (29). Ideally, measured differential phase should be equal to real differential phase, regardless of the amount of *LDR*.

Fig. 10 shows the effect of the target depolarization on the measurement of the differential reflectivity, Z_{DR}. The accurate value of Z_{DR} in this case was -3 dB. The switching polarization scheme and the extended polarization scheme will measure the reduced Z_{DR} value due to the presence of significant *LDR*, but they will not couple differential phase into said measurement.

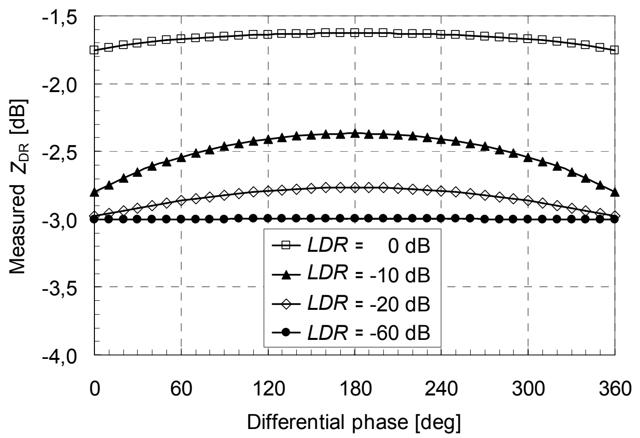


Fig. 10. Simulated measurement results of the differential reflectivity using the hybrid polarization scheme, according to (28). All three schemes will be affected by the presence of *LDR* (reduction of measured Z_{DR}), but hybrid scheme also couples differential phase into the Z_{DR} measurements.

5. Conclusions

The three polarization schemes used recently in atmospheric radar systems are analyzed: the switching polarization scheme, the hybrid polarization scheme and the extended hybrid polarization scheme. Performance of a polarimetric radar system using each of these schemes is simulated.

The most widely used polarization scheme is the switching polarization scheme. Hardware required for the implementation of this scheme is relatively complex and expensive. However, extracting the polarimetric parameters using this polarization scheme is fairly simple.

The hybrid polarization scheme was most extensively analyzed. This scheme promises relatively simple and inexpensive radar design. Furthermore, since it uses circular polarization, this scheme is sensitive to shape of the hydrometeors but not to the orientation, which is reported in [1] to be of some importance. However, analysis showed that a major disadvantage of this polarization scheme is intermixing the propagation media properties with the observation target properties. This problem arises from the fact that radar transmits two polarizations at the same time and contaminates cross-polarization response. This polarization scheme is good for meteorological measurements that do not involve depolarizing targets (e.g. precipitation). For the cloud microphysics research, this method might prove inaccurate due to the presence of depolarizing targets.

The extended hybrid polarization analysis suggested this polarization scheme as the means to keep meteorological advantages of the circular polarization. The extended hybrid polarization scheme is slightly more complicated in hardware, but offers relatively simple data retrieval. The radar system implementing this polarization scheme can be easily reverted back to normal hybrid scheme.

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