Improving Cross Polarization for MPAR via Orthogonal Waveforms

LOCKHEED MARTIN

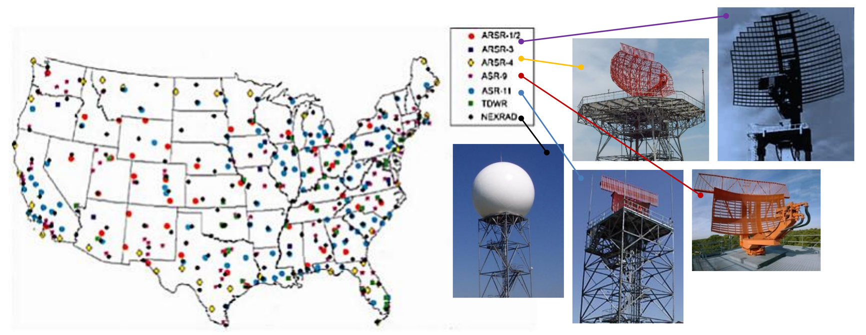
Dr. Yasser Al-Rashid, Dr. Rao Nuthalapati , Mr. Francis X. McGroary, Dr. Charles Kryzak, Dr. Svetlana Bachmann

Background: Multifunction Phased Array Radar(MPAR)

The Department of Commerce / National Weather Service (DoC/NWS), the Department of Transportation / Federal Aviation Administration (DoT/FAA), and the Department of Defense (DoD) maintain several networks of independent ground-based radars (NEXRAD, TDWR, ASR, ARSR) for weather surveillance and air traffic surveillance and control.

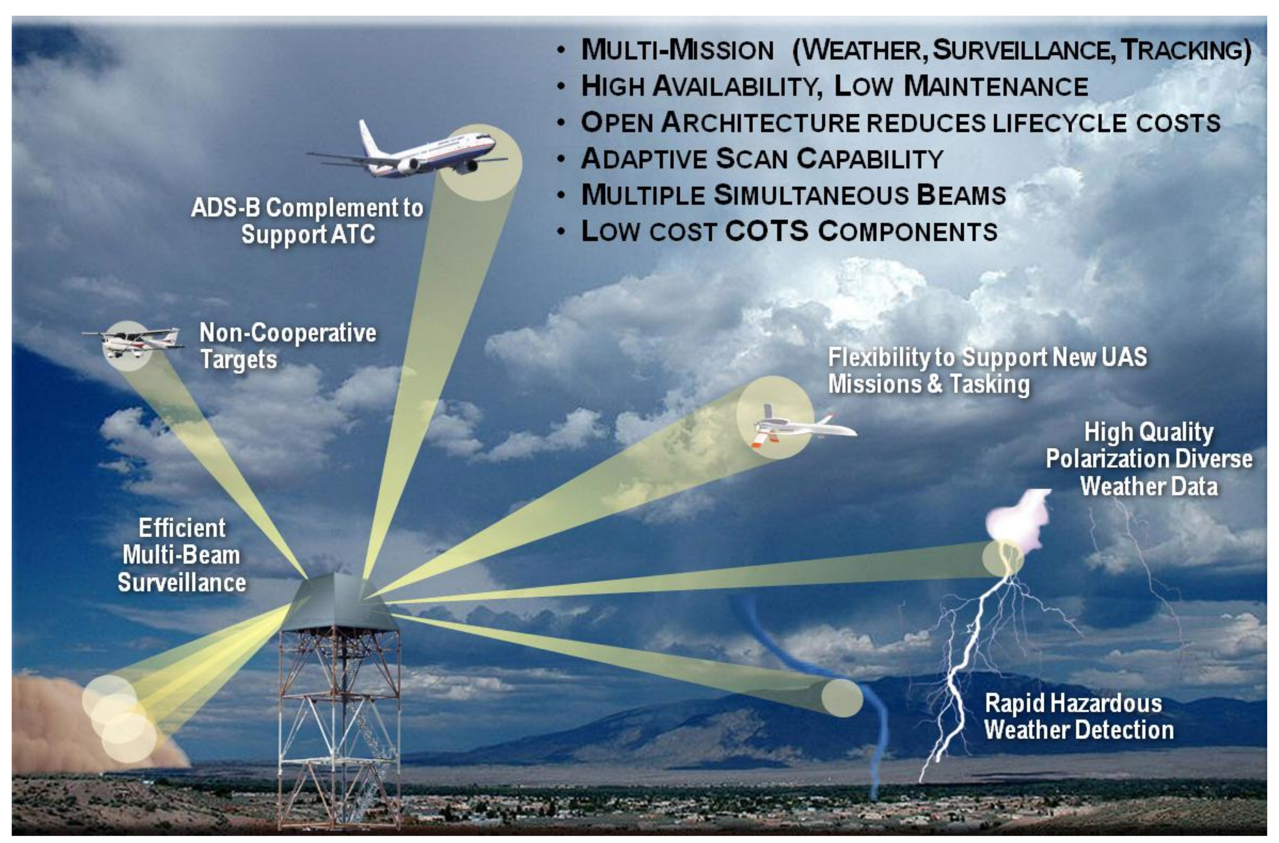
Network	# of radars	Deployment	Frequency band	Polarization	Antenna Size	Beam (Az x El)	Volume Scan
WSR-88D	156	National Grid	S	Linear H, V	d=8.5 m	0.95°	4-6 min
TDWR	45	Large Airports	C	Linear H	d=7.6 m	0.55°	1-5 min
ARSR	101	Nationwide	L	Linear V, Circ	12.8 9.9m	1.4 2.2°	36 s
ASR	233	Commercial Airports	S	Circular	5 3 m	1.4 5°	5 s

Locations of U.S. operational weather and air traffic control radars.
Source: OFCM 2006



The NWS is in the process of deploying the dual polarization (dual-pol) upgrade on its NEXRAD network. Even with the upgrades, the newest of radars in these networks are based mainly on technology a decade or more old. As the legacy systems age, agencies are considering a consolidated network of Multifunction Phased Array Radars (MPAR).

MPAR enables flexible multi-mission operations



For weather surveillance, **MPAR** will need to provide dual-pol capability comparable with NEXRAD. The operational NEXRAD with parabolic dish antennas have extremely good cross polarization isolation (x-pol) between the Horizontal (H) and Vertical (V) channels. Good x-pol enables accurate measurement of polarimetric variables and subsequent classification of all states of hydrometeors and other scatterers. It is understood that any radar to replace the current NEXRAD system must demonstrate similar x-pol characteristics.

Date : 22-26 January 2012
Event : the 92nd American Meteorological Society Annual Meeting
Location : New Orleans, Louisiana
Theme : Technology in Research and Operations
Topic : Emerging Technologies
Title : Improving Cross Polarization for MPAR via Orthogonal Waveforms

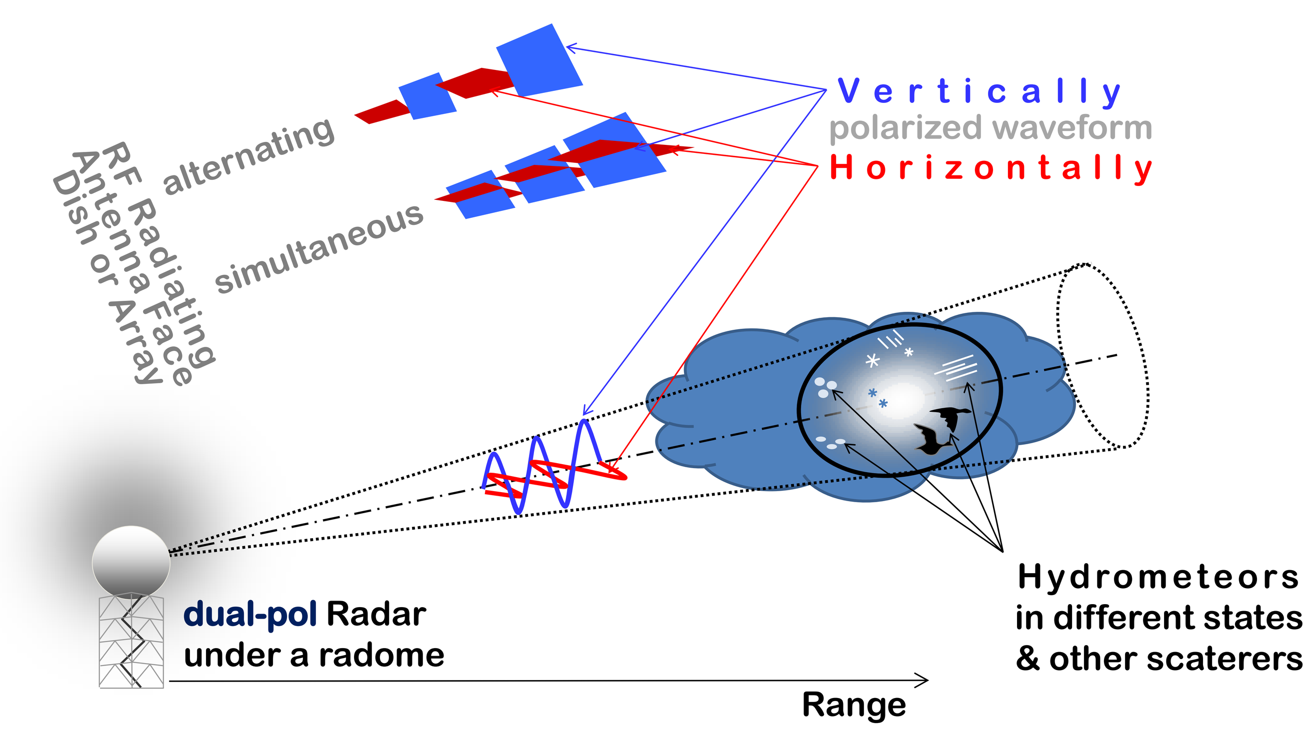
Background: dual-pol

Dual-pol provides indispensable information enabling echo classification and rainfall estimation. Dual-pol is a capability of a radar system to transmit/receive linear horizontally and/or vertically polarized waves in a simultaneous and/or alternating fashion, enabling one of the following modes:

STSR simultaneous transmit simultaneous receive
STAR simultaneous transmit alternating receive
ATSR alternating transmit simultaneous receive
ATAR alternating transmit alternating receive.

Each polarization mode offers a unique set of benefits and limitations. All 4 modes have presently been implemented. Depending on the system mode, the requirement for dual-pol quality is different (less stringent for A, more stringent for S)

Radar	Responsible Institution	Location	Mode
CAMRa	Reading University	Chilbolton, U. K.	ATSR
S-Pol	National Center for Atmospheric Research	Boulder, Colorado, U.S.	ATSR, STSR
CP-2	Australian Bureau for Meteorology	Brisbane, Australia	ATAR
KOUN	National Severe Storms Laboratory	Norman, Oklahoma, U. S.	STAR , STSR
SCU-CHILL	Colorado State University	Boulder, Colorado, U.S.	STAR , STSR
MPAR	Office of Federal Coordinator for Meteorology	TBD, U.S.	STAR ?



Background: x-pol

co-pol is the desirable transmitted signal.
x-pol is the interfering transmitted signal.
x-pol is orthogonal to the polarization being discussed.

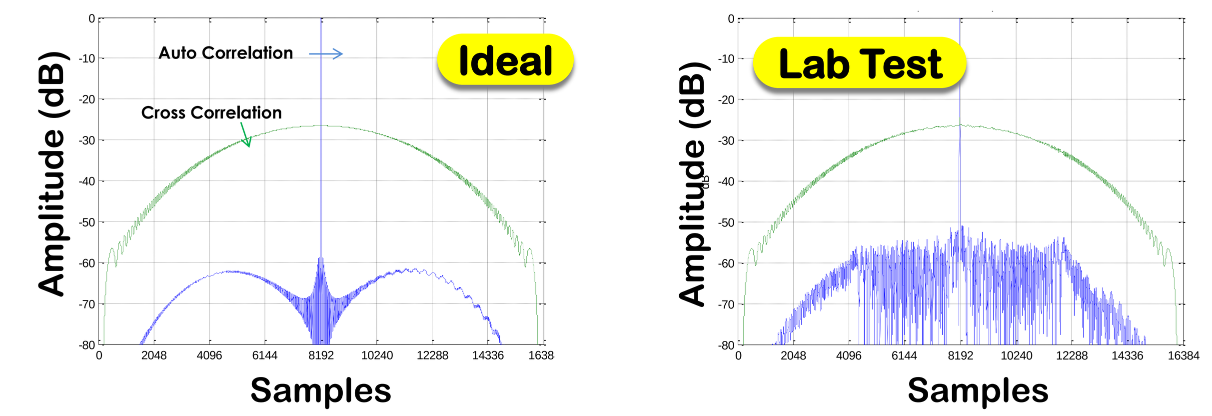
Dual-pol quality is described by the cross polarization isolation of the antenna. Each radiating element has intrinsic x-pol. An array of RF elements has a collective x-pol which can be manipulated across the array to achieve desired characteristics. Array tuning is a common procedure. Additional special tuning to reduce x-pol can be implemented with additional hardware and software, potentially impacting the cost of the array. It is very important to set the requirement for dual-pol quality noting that A T/R modes are cheaper compared to S T/R modes.

Demonstrating Dual-Pol Quality

Our research and development efforts are aimed to address potential risks from replacing legacy dish radar with a modern phased array radar. One focus area is in achieving the high dual-pol quality on an antenna with many radiating elements.

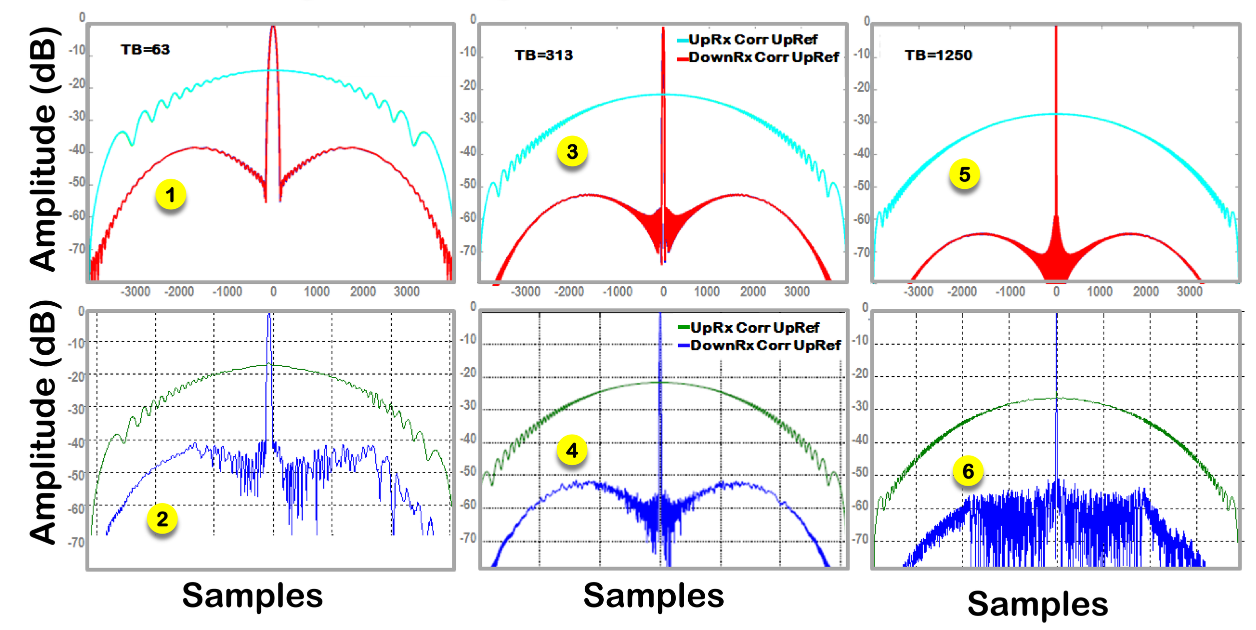
Orthogonal LFM cross correlation

Orthogonal Linear Frequency Modulated (LFM) method is based on cross correlation between up-chirp and down-chirp. The benefits of the orthogonal LFM on the x-pol performance were demonstrated via simulation in 2010 Ideal . We validated the performance of a dual-pol antenna panel that was assessed in simulations by demonstrating the performance on an existing S-band phased array panel with 144 dual-pol radiating elements Lab Test



A set of waveforms with different Instantaneous Bandwidth and Pulsewidth products were used to assess cross correlation and sidelobe performance. The results indicate that the orthogonal waveforms further improve x-pol.

Pulse width (ms)	Band width (MHz)	up-chirp / down-chirp Isolation (dB)		Pulse Compression Weighting Loss (dB)	Integrated Sidelobe Level (dB)
		Simulated	Measured		
63	1	1 -14.48	2 -14.5	-1.87	-21.70
125	2.5	3 -21.44	4 -21.5	-1.87	-28.60
250	5	5 -27.46	6 -27.5	-1.87	-34.38



The simulations depict improvement ranging from 14 dB to 27 dB. For wider time-bandwidth products, even more improvement is attainable. Next we applied orthogonal LFM to an existing dual-pol array and observed the same trend in the x-pol isolation.

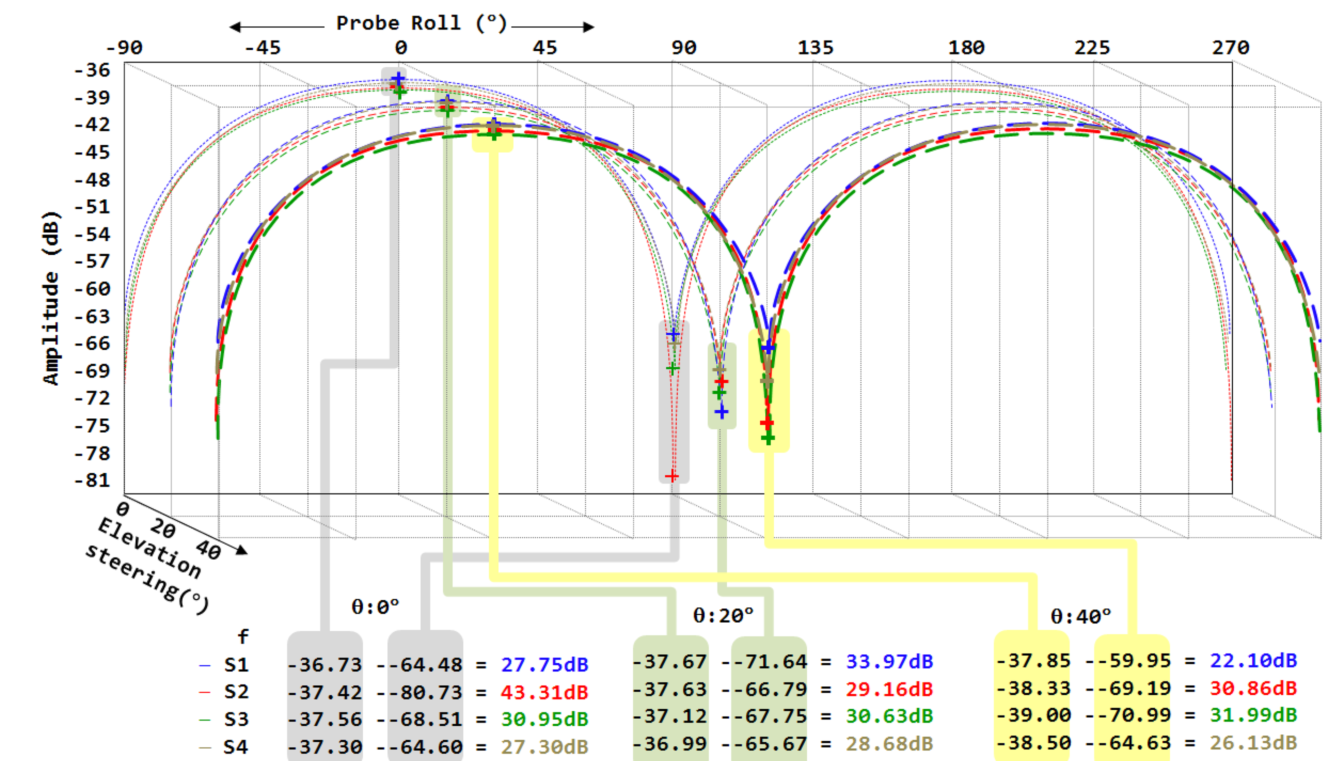
Anechoic Chamber

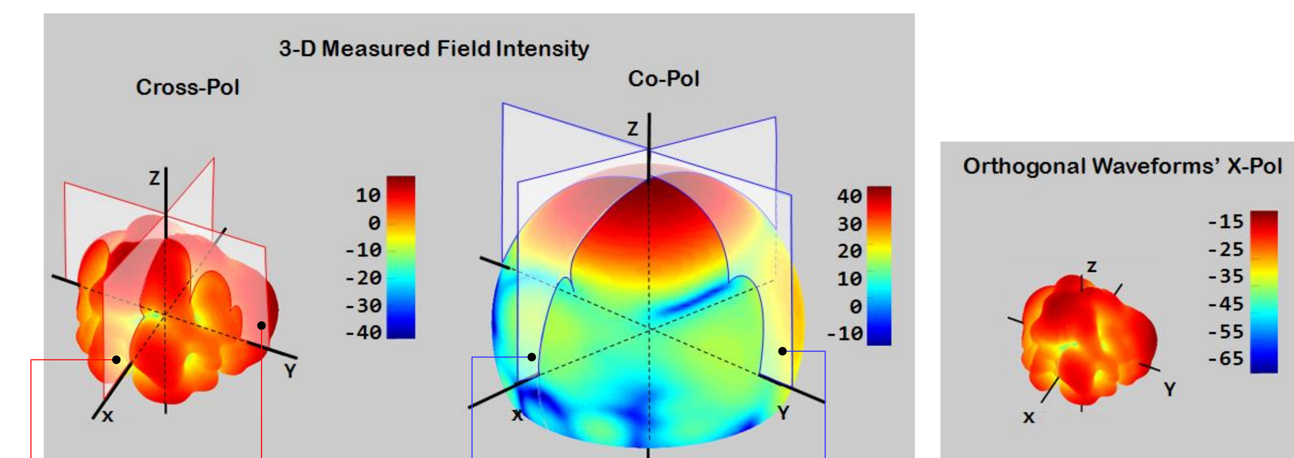
The panel was tested in Syracuse, NY in the 11,300 ft² anechoic chamber with 30' x 30' vertical planar, laser controlled scanner coupled to a high-speed microwave measurement system for fast antenna measurements. Antennas ranging up to 25 ft in diameter and operating within 1–18 GHz are tested here.

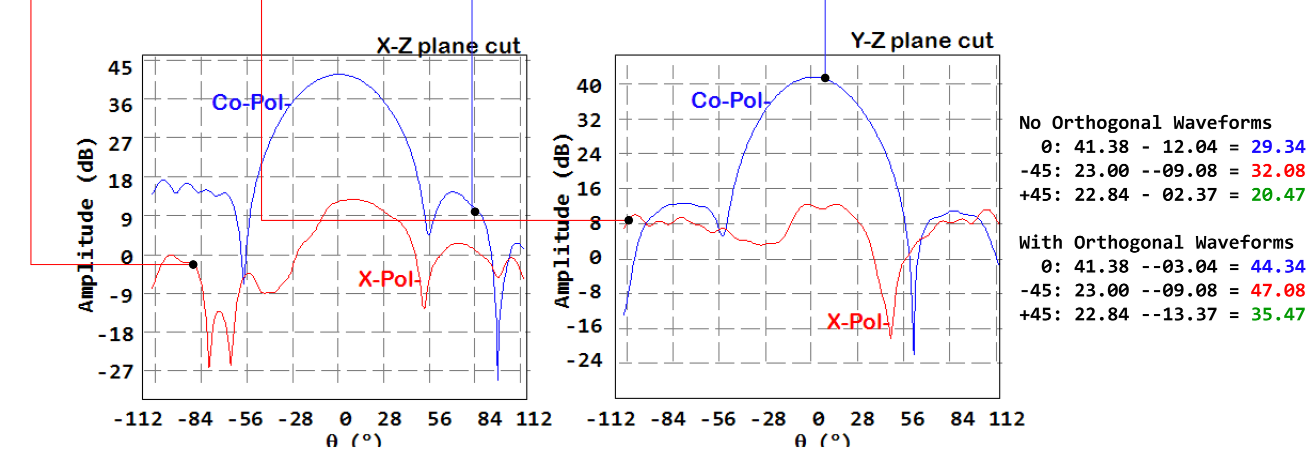
The RF was transmitted using a horn antenna. The panel was used on receive. The polarization on the horn antenna was switched between horizontal to vertical multiple times. Orthogonal waveforms were synthesized for multiple frequencies. Recorded data was processed offline. Cross-correlation between the signal in each polarization and the stored waveform replica was assessed to evaluate the cross-polarization characteristics. Different frequencies were used in the evaluation.

Measured X-Pol

A pure native element behavior (without calibration) for one element embedded in the S-band 144-element array is shown at boresight, 20°, and 40° elevation steering. The element is a dual resonating patch.







The overall system x-pol is enhanced by 14 – 27 dB depending on the time-bandwidth product of the orthogonal waveform used. In this case 20 dB additional x-pol isolation was achieved.

Conclusions

Antenna cross polarization isolation can be improved using (1) hardware and/or (2) waveforms\processing .

The existing subarray designs are available to directly compare x-pol and dual coefficient weightings needed to meet x-pol behavior and steering requirements. Regardless of the hardware/processing approaches, the application of orthogonal waveforms provides additional 14-27dB improvement on x-pol as demonstrated in simulations in 2010 and testing in the anechoic chamber in 2011.

Dual-pol quality suitable for stringent polarization requirements is achievable.