International Journal of Advance Research in Science and Engineering
Vol. No. 5, Special Issue No. 01 , May 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

RADAR ANTENNAARRAY

[1]Abdelrasoul Jabar Alzubaidi, Elsanosy M. Elamin[2],

Murtada M. Abdelwahab[3]

[1]Sudan University of Science and Technology, Engineering Collage,

School of Electronics, Khartoum, Sudan.

[2]Electrical Engineering Department, Faculty of Engineering, University of Kordofan, Elobeid, Sudan

[3]Department of Electronic Engineering, Faculty of Engineering and Technology, University of Gezira, Madani, Sudan

ABSTRACT

This paper deals with the implementation of phase-tilt radar antenna array for sensing the atmosphere.It describes the X-band Phase-Tilt Radar antenna array being developed at the Engineering Research Center of Sensing the Atmosphere (CSA) for use in distributed, collaborative and adaptive sensing networks. The architecture of the radar and its component parts including the T/R module, passive antenna elements, and array controller are described in detail. Test data for the full array will be also presented.

Keywords: Phased Array; Dual Polarization; T/R Module; Radar; Center of Sensing the Atmosphere (CSA).

I INTRODUCTION

Advances in semiconductor technology have enabled a wide variety of electronic devices. The Center of Sensing the Atmosphere (CSA) is developing small, low-power X-band radars that are used in dense networks to improve the scanning of the atmosphere. Dense networks of short-range radars can defeat the blockage due to the curvature of the earth, which limits today's long-range radar networks from viewing weather hazards and aircraft at the earth’s surface. They also enable high spatial and temporal resolution views of the lower-troposphere with the potential to scan up to the tops of storms. Currently, the center has installed a network of four small radars to proof the concept of adaptive scanning and high resolution view of the atmosphere. The radars used in this test bed utilize highly agile mechanically-scanned antennas, but the next step in the evolution of this technology is to realize these radars using solid-state microwave technology in phased array antennas. Dual polarized phased-array antennas present a new challenge for weather radars. Unlike conventional reflector antennas, co-polar main beam patterns, sidelobes and cross-polarization isolation change with scanning beam position in electronically scanned arrays. A quantitative evaluation of the measurement accuracy in differential reflectivity due to cross-polarization isolation limitations is described. According to this evaluation, cross-polarization isolation levels better than(-20dB) are needed to avoid contamination of less than (0.1 dB) when using alternating polarization mode. Current state of the art implementations of 2 dimensional phased array antennas are very expensive due in part to the high cost of the T/R modules populating the antenna. While technology is advancing to reduce cost in the phased array antennas for radar and communication applications, CASis using the today’s technology to develop a one dimensional dual-polarization active array antenna called the Phase-Tilt antenna. The Phase-Tilt antenna is composed of an active linear array and a mechanical actuator which allow the antenna to perform electronic scanning in azimuth and mechanical scanning in elevation. The linear array is a planar structure 68 columns or sub-arrays; each column is made up of 32 dual-polarized aperture coupled microstrip patch antennas interconnected by series-fed networks in each polarization. The 64 inner columns are fed by dedicated T/R modules, which provide phase, amplitude and polarization diversity and the 8 remaining outer columns are used as dummy elements to reduce the effects of diffraction and non-uniform mutual coupling. Control of the phase and amplitude for beam steering and aperture power distribution in the azimuth plane is accomplished through an FPGA based micro-controller that communicates with the T/R modules and serves as the master timing control.

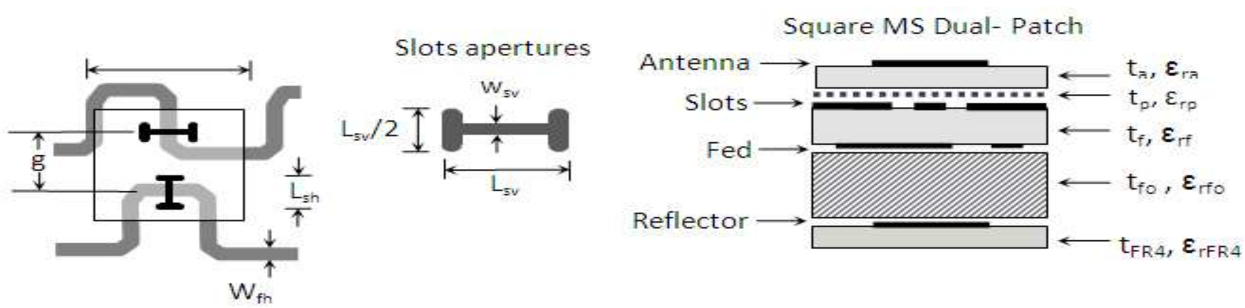
II ANTENNA ARCHITECTURE

The Phase Tilt radar is composed of several major subsystems. The Phase Tilt antenna is one of those subsystems and it can be broken down into four major sets of components; passive antenna array, T/R module, signal distribution backplane and array controller. The 64 T/R modules are grouped into 4 sets of sixteen elements, each with a passive array and backplane. The array controller is the interface between host computer and the antenna. The controller communicates with the T/R modules to set the azimuth beam position and the tilt controller to set the elevation position. In addition, it serves as the master timing control and generates all triggers and switching signals.

III ANTENNAARRAY

3.1Radiating Antenna Element

The radiated antenna element is a dual polarized aperture coupled microstrip patch antenna. This antenna element type provides less spurious radiation and also facilitates the design to achieve low cross-polarization coupling for a series-fed linear array. Two orthogonal dog-bone shape slots are used for H and V polarization because of the small size and better coupling with respect to the rectangular slots. The size and their positions relative to the patch permits the control of the level of coupling for each polarization and their respective impedances. The antenna element was designed at 9.36 GHz and impedance bandwidth of 100 MHz. The antenna substrate structureconsists of four dielectric layers. The first two are low loss microwave substrates for the series-fed lines and patches. The third dielectric material is rigid foam that essentially serves as a spacer, used to reduce the back lobe radiation to (-25dB) with respect to the main beam.

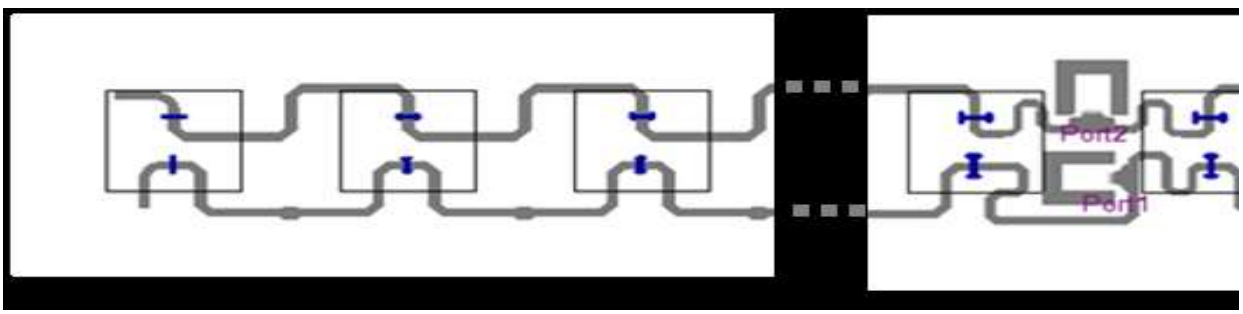


Figure(1) Dual Polarized Patch and stack up

The microstrip patch antennas are excited by two serpentine lines, one for each polarization. Each serpentine line excites an aperture slot (orthogonal to each other) behind each patch to obtain linear dual-polarized fields. In this design, the dog-bone-shaped aperture slot emits less spurious radiation that helps to improve the cross-polarization isolation of the antenna. Typically, rectangular slots apertures are located at the center of the patch to obtain maximum energy coupling for the feed. In this design an orthogonal arrangement of the slots, known as "T" slots, is implemented to improve the cross-polarization andport isolation. The dimensions of the dog-bone-shaped aperture (Ls and ws) and their position under the patch were defined according with the patch antenna dimension (Lph and Lpv) in order to have the antenna element resonate at 9.36 GHz.

3.2 Array Antenna

To interconnect the 32 elements in the column, two serpentine lines are used to serially feed each element in both polarizations. The series-fed configuration offers the advantages of being less complex use less substrate area and also presents less loss, compared with a corporate feed. The drawback of the series-feed is that the amplitude and phase are frequency dependent, limiting bandwidth, and the multiple bends can affect the amplitude distribution and progressive phase required to achieve low sidelobe levels. The serpentine lines are fed from the center using a T-junction divider with the lower half of the column being a mirror of the upper half. The horizontal polarization is unaffected by the mirroring, but the vertical polarization requires an additional 180° phase shift. The spacing between elements of 17 mm (0.53λ0) was used in order to accommodate the serpentine lines, power dividers and connectors in the feed layer.



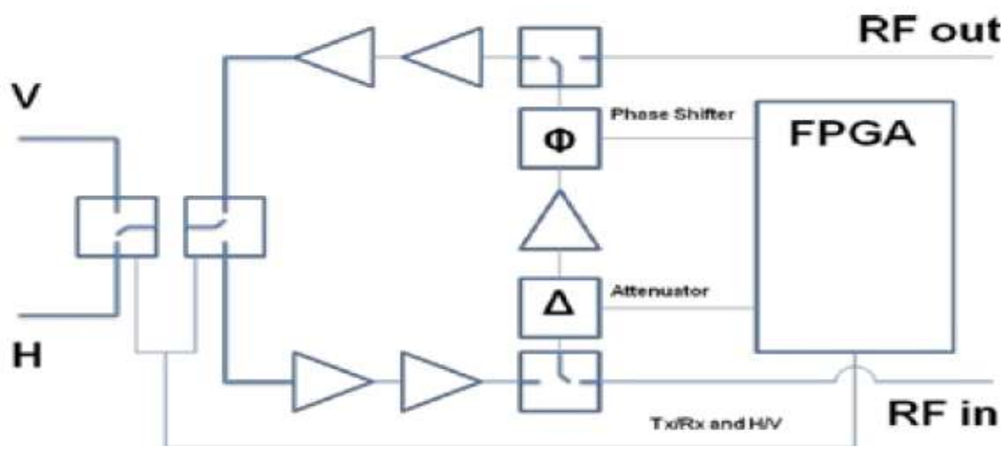
Figure(2) Linear array antenna for elevation plane

Figure(3) illustrates the center of a linear array antenna of 1x32 elements. An update to the technique that includes the effect of the mutual coupling was implemented in order to obtain better results in the antenna impedance, amplitude and phase distribution along the linear array. In the column, each element and its slot appears as series impedance along the feed line.

IV T/RMODULE AND BACKPLANE

A block diagram of the T/R module is given in Figure(3). The T/R module architecture uses a "Common Leg" in both transmit (Tx) and receive (Rx) channels. The transmitter and receiver channels have independent input and output ports and share a common attenuator, gain block and phase shifter. Two T/R switches connect the common patch control circuitry to the transmitter and receiver blocks. The transmitter block consists of a high and medium power amplifier and the receiver block is comprised of a low noise amplifier and gain block. A custom designed high power Junction/Diversity Switch is a necessary component used to connect the two allowing transmit/receive and polarization diversity. The single transmit and receive channels limit the operation to alternating polarization mode.

The T/R modules has an integrated Field-Programmable Gate Array (FPGA) used for component interfacing, controlling the attenuator, phase shifter, T/R switches, and load switches for the amplifiers. Additionally, the FPGA reads the register of a temperature sensor located on the module. The on-board FPGA is locally programmable with an external PROM (Programmable Read-Only Memory) and has a dedicated 25 MHz crystal clock. The FPGA's internal memory is configured to be used as look-up table, which stores the attenuator and phase shifter states for 256 beam positions for four operation modes (TxV, TxH, RxH, RxV). A separate memory table, referred to as the sequence table, holds the look up table addresses for the polarimetric pulsing sequence to be performed. Since the sequence table holds only addresses, its values are common to all T/R modules. The distribution backplane consists of two 16:1 power combiner/dividers, a power distribution bus and a 25 MHz bus for communication to the T/R modules. Individual T/R modules can be addressed by means of point to point commands that load the lookup table or directly control the phase shifter and attenuator output registers. When broadcasting the sequence table data, a point to multi point mode is used so that all T/R modules receive the data at the same time.



Figure(3) T/R module block diagram

V ARRAY CONTROLLER

The array controlleris a Field Programmable Gate Array (FPGA) based microcontroller that controls communication between the host computer and the T/R modules and also serves as the master timing generator. Currently, the array controller interfaces with the host PC over a RS232 connection, but an Ethernet based connection is planned. T/R modules are connected to the array controller through a serial transmitter and receiver operating at 25 MHz.

In operation, the array controller receives the T/R module look up table data from the host computer and stores it in the off chip DDR SRAM. The controller then reads the data out of memory and sends it to the transmit FIFO which connects with the serial transmitter. The transmitter broadcasts the data over the bus using a point to point data format. The T/R module that is addressed echoes back the message to the array controller receiver where it is compared to the original message to verify that it was sent properly.

After the look-up tables have been loaded, scan and timing data are sent from the host to the array controller. The host computer loads a scan, a series of azimuth beam positions at a fixed elevation, into the array controller memory. Each beam position has an associated 8 state polarization sequence (composed of TxV, TxH, RxV and RxH), the number of times the sequence is repeated (hereinafter referred to as the loop count), and the Tx pulse length and pulse repetition time (PRT). When the scan is loaded, the array controller first sets the elevation through the tilt controller. It then routes the first beam position's sequence to the transmit FIFO that broadcasts the data to all of the T/R modules in a point to multipoint operation. While the sequence is being broadcast, the pulse length, PRT and loop count are loaded into the timing state machine. When the serial transmitter has finished loading the sequence into the T/R modules, the timing state machine is started which generates the switching signals for the T/R modules and the triggers for the digital transceiver. One pass through the state machine steps the T/R modules through the sequence table one time generating four pulses. The state machine repeats the sequence until the loop count is reached. The second beam position is then read from memory and the process is repeated. When the final beam position in the scan is reached, the host computer loads the next scan.

VI SOFTWARE PROGRAM & ALGORITHM

To program the FPGA using VHDL language, we need to go through four steps as follows:

1. Step one is developing a VHDL program in the computer by using Spartan-3 software.
2. Step two includes VHDL synthesis in the design, which converts the design in the behavioral description file into gates. The synthesis tools figure out what gates to be used based on the VHDL program file.
3. Step three includes downloading of the program into the FPGA.
4. Step five includes testing and debugging the operation of the whole system.

To perform control of the attenuator, phase shifter, T/R switches, and load switches for the amplifiers,a sequenceof 256 times need to be repeated continuouslyin order to alter the polarization mode. The algorithm is:

Start

Initialization:

--- Generate a look up table of 256 locations.

--- Generate a sequence table containing the address of the look up table.

Alter polarization:

…. Initialize counter = 256.

Repeat control:

… Access the sequence table.

….Acquire the address from the sequence table.

… Point to the look up table.

….Get the control data from the look up table.

…. Apply the control data to the T/R switches.

… Decrement counter.

--- If the (counter = 0) then go to Repeat control.

--- Go to alter polarization:

End.

Note that the FPGA connector (A2) is programmed for data output to control theT/R switches, and load switches. The timing to control the T/R switches, and load switches depends upon the clock of the FPGA.

VII. RESULTS

Four antennas of 18x32 elements were implemented and tested. S-parameter and dual-polarized patterns in the elevation plane were measured and reported. For the entire frequency range (9.3 Ghz to 9.4 GHz) the first sidelobe is below -24 dB and the pattern roll-off decays rapidly from broadside. The cross-polarization, presents values of -35 dB and -32 dB at broadside for V and H respectively.

VIII. CONCLUSIONS

A prototype antenna has been designed, fabricated and tested. It meets the polarization requirements needed by and defines a new state-of-the-art for remote sensing of weather using small radars. The prototype antenna will be mated with standard signal processors to serve as a proof of concept radar for use in test bed. Additional units can be built for exploring networks comprised of many antennas arranged in a dense network.

REFERENCES:

[1] D.J. McLaughlin, E.J. Knapp, Y. Wang, V. Chandrasekar, "Distributed Weather Radar Using X-Band Active Arrays", Radar Conference, 2007, IEEE.

[2] Yanting Wang and V. Chandrasekar, "Polarization isolation requirements for linear dual-polarization weather Radar in simultaneous

[3] Salazar, J.L., R Medina, E. J. Knapp, and D. J, McLaughlin, 2008: "Phase-tilt array Antennas Design for Distributed Radar Network for Weather Sensing". IEEE International Symposium on Geosciences and Remote Sensing, Boston, MA.

[4] A.P. Hopf, J.L. Salazar, R. Medina, V. Venkatesh, E.J. Knapp, S. Fraiser and D.J. McLaughlin: Casa Phased Array System Description, transmission mode of operation", IEEE Trans. On Geoscience and Remote Sensing, Volume 44, Issue 8, pp. 2019 – 2028, Aug. 2006.

[5] D. M. Pozar and S.D., "Improved Coupling for Aperture Coupled Microstrip Antennas", 1991 IEEE Electronics letters, Vol.27 No.13, June 20th 1991.

[6] D. M. Pozar, "A Review of Bandwidth Enhancement Techniques for Microstrip Antennas", pp. 157-166, in Microstrip Antennas, IEEE Press, 1995

[7] Salazar, J.L., R Medina, E. J. Knapp, and D. J, McLaughlin, 2010: "Dual-polarization performance of the phase-tilt antenna array in a CASA dense network radar", IEEE International Symposium on Geosciences and Remote Sensing, Hawaii.

[8] J. Salazar, E. Knapp, D. J. McLaughlin. "Antenna Design Tradeoffs for Dense Distributed Radar Network for Weather Sensing", Preprints Proceedings of 33rd International Conference on Radar Meteorology 2007, Cairns, Australia