AhEAD

Advanced dEsign and testing of a polArimetric X-banD antenna for avionic weather radar

State of the art – Background

Modern weather radars on-board commercial aircraft first arrived around in the 1950's, with the intent to detect and avoid storms along the flight path.

Most of today's airborne weather radars operate in the X-band, whereas ground based weather systems usually operate in the S-band or C-band. In the realm of ground radars, dual-polarization technology is being introduced on these S-band and X-band systems, following extensive work by the NOAA and others. In 2013, all US-based NEXRAD ground weather radars were equipped with dual-polarization.

Dual-polarized weather radars offer clear advantages with respect to accuracy and versatility. With the merging of data from the two polarizations, the radar system will be able to establish differential reflectivity, correlation coefficients, linear depolarization and specific differential phase. These lead to better performance in detecting tornadoes, better rainfall prediction, precipitation types, icing detection and 3D-cloud build-up. In turn, these benefits will allow improved trajectory management.

However, airborne radar systems face much more stringent requirement and boundary conditions than their ground-based counterparts. This is particularly the case for the antenna. Further, dual-polarization has been demonstrated for other applications, but not for a nose-mounted set-up. The nose-mounted set-up for dual-polarized weather radar poses form-fit requirement that are extremely tight. Also weight, power and cost concerns pose a very significant economic issue particularly for the aviation environment.

The antenna is one of the most critical components in the realization of avionic polarimetric weather radars for a number of reasons:

a) Stringent performance required in terms of polarization (co/cross coupling; polarization purity of each channel), while maintaining usually applied requirements in terms of beamwidth and side-lobe level; also considering the effects that the antenna radome can have on e.m. field polarization while changing the steering of the antenna beam
b) Weight and size
c) Mechanical/electrical interface to aircraft
d) Compatibility with other on-board electrical/electronic devices
e) Environmental constraints

While points (b-e) are more or less common also to currently applied non-polarimetric radars, point (a) is peculiar of polarimetric antennas.

The AhEAD project aims at designing, breadboarding and validating a dual polarized antenna suited for polarimetric weather radar to be installed on aircraft.

The proposed antenna solution is the result of an articulate study and design process based on the following main activities

- Definition of Requirement
  General requirements of weather radar and also specific of polarimetric antennas were considered
- Review of state of art of polarimetric antenna technologies and assessment of candidate technologies
- Selection of two possible candidates and preliminary analysis
- Detailed design of the most promising solution
- Prototyping, measurement and validation
- Antenna evaluation and roadmap for full device development

Objectives

The AhEAD project aimed at developing an antenna to demonstrate the feasibility of a polarimetric antenna with the required electrical performances to be effectively applied in a polarimetric weather radar system for avionics

Several antenna technologies have been considered as potential candidates, mature and consolidated such as Slotted Wave guide and printed antennas as well more innovative solutions SIW and connected arrays.

A printed antenna was finally selected as baseline for a number of suitable features for the commercial aircraft field of application:

1. Low mass
2. Low cost
3. High flexibility and modularity
4. manufacturing process well-evolved

5. very large range of high quality substrates to design high performance antenna
6. high degree of system integration
7. quite accurate translation from CAD model to the actual hardware up to Ka-band
8. Good electric performances

Slotted wave guide based solutions represent surely a valid alternative, but were finally discarded principally because many patents exist specifically mentioning weather polarimetric radar.
The antenna design was mainly driven by the very demanding requirement in terms of electrical performances, particularly referring to the dual polarization feature.
In the following the main driving requirements have been summarized for the target antenna size of 28" that has been considered in the project:

1. Band: 9300 – 9500 MHz
2. RL<-17.7dB
3. SLL<-30 dB
4. HPBW< 3.7°
5. Power 300Watt
6. Losses 2dB
7. XPD 35dB
8. Port isolation -35dB

As regarding printed technology, one of the most critical item was the ohmic loss. For this reason a series fed u-strip beam foarming network was applied.

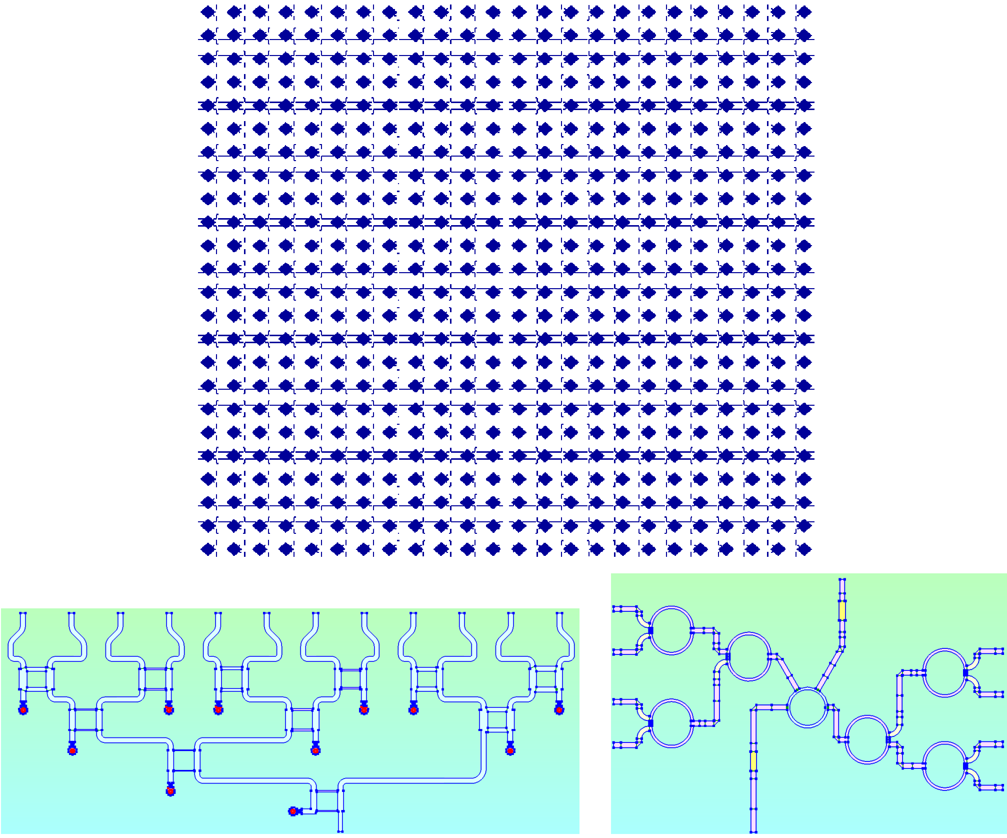
Description of work

To achieve The Project objective a number of actions have been identified and organized in 8 work packages:
WP1 – Project Management, has the aim of supervising the project implementation and let the activities be effective in reaching the project objective and the expected results.
WP2 – Problem assessment and requirement definition, has first of all the aim of reviewing and agreeing with the Topic Manager the scope of the work and the Project program. Further, it has the goal of identifying all the requirements of the application in object from which the antenna specifications that have driven the next steps of the Project were assessed.
WP3 – *Antenna design*, this part of the activity started from the analysis of the state-of-the-art, in order to identify possible technological solutions to be traded-off. Two candidate solutions (indicatively) were identified to be worked out up to the level of "Preliminary Design" and their performance were compared in order to select the most promising configuration. Finally a series fed printed antenna was further worked-out up to "Detailed Design" level. A breadboard configuration (representative of the antenna functionalities and critical issues) was defined
WP4 – *Antenna breadboard manufacturing & testing (measurement)*: the breadboard configuration was manufactured and its electrical and radiating performance was measured in suitable measurement facilities. The measured data was compared and integrated with the simulated ones in order to complete the validation of the antenna design.
WP5 – *Design evaluation*. antenna performance were reviewed and critical issues identified. Points of improvement and feasible upgrade to the design were analysed and proposed.
WP6 – *Dissemination*, A Project Web Site was created

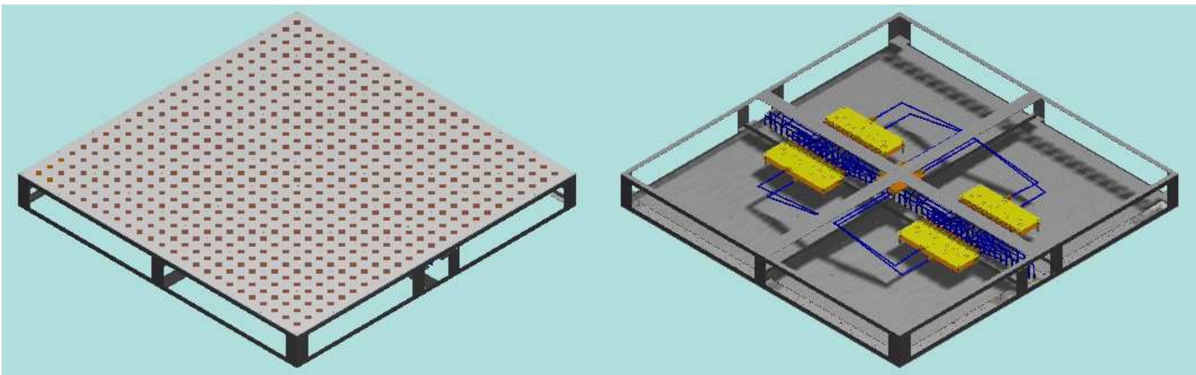
Results

A dual polarized array antenna was designed, manufactured and tested.
The proposed antenna design seems very promising in terms of SWAP – C ("Size Weight and Power – Cost") performances, due to the printed circuit technology selected.
Electrical performances seem promising too, nevertheless further activities of tuning and optimization of the design are necessary.
The currently available design configuration can be reasonably considered a technical demonstrator, a starting point for a path towards the desired industrial product. The demonstrator can be offered to industrial actors operating in the avionic radar field or can be further developed by the AHEAD partners themselves, pending the results of a market analysis and a business plan.

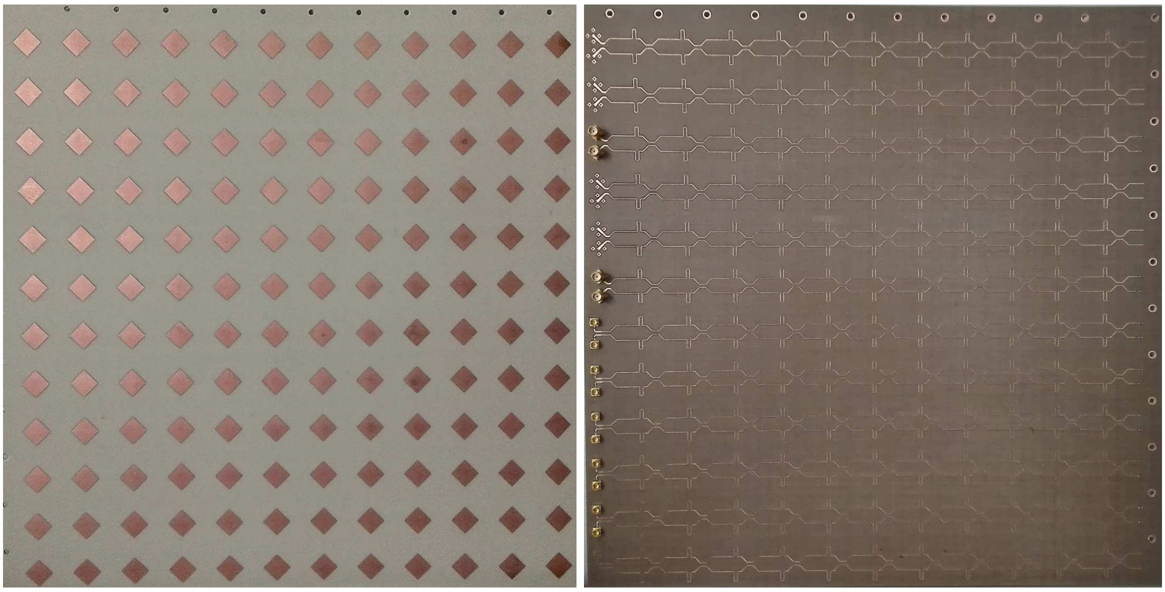
Picture, Illustration



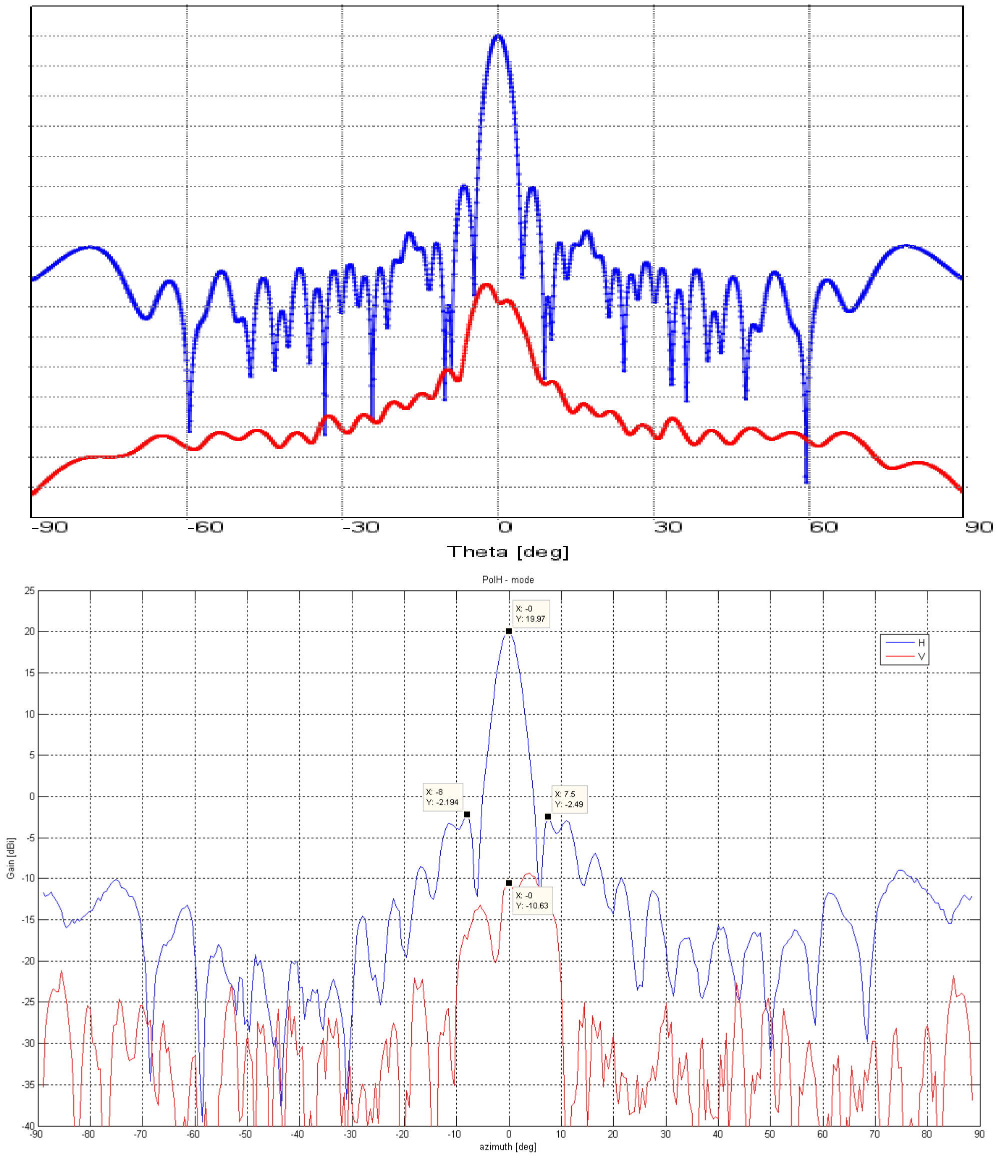
Antenna e.m. model



Antenna CAD



Antenna Bread-Board



Antenna estimated and measured pattern

Project Summary

Acronym :	AhEAD
Name of proposal:	Advanced dEsign and testing of a polArimetric X-banD antenna for avionic weather radar
Technical domain:	Antenna Demonstrator
Involved ITD	Clean Sky SGO
Grant Agreement:	632453
Instrument:	Clean Sky JU
Total Cost:	455.728,09
Clean Sky contribution:	271.652,26
Call:	JTI-CS-2013-02
Starting date:	16/06/2014
Ending date:	15/03/2016
Duration:	21 months
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