FPIR DEMONSTRATOR

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1. INTRODUCTION

Full Polarization Interferometric Radiometer (FPIR) is a light weight high resolution imaging polarimeter at X-band based on one dimensional aperture synthesis [1]. Differing from ESTAR-like precedents [2] on dual or full polarization, conical antenna beam and 2-point calibration. FPIR concept is proposed to Soil Moisture and Ocean Salinity (SMOS) follow on mission as an secondary payload in order to calibrate the impact of surface roughness when retrieve the ocean salinity. Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) [3] and FPIR will work together and produce brightness images with polarimetric information at both L and X band, respectively. FPIR system is optimized taking into account the strict constraints on accommodation, structure, stability, mass and power by the Y shape array of MIRAS.

Moreover, FPIR is a better solution for high resolution passive microwave imaging due to its light weight, electrical scan, relatively simple electricity and easy accommodation, as compared with the mechanically scanning radiometer with large real aperture reflector. The instrumentation is feasible from L to Ka band to measure geographical parameters of atmosphere, land and ocean with low cost and risk reduction. Retrieved information will help to improve weather forecast and study of climate change.

The development of FPIR demonstrator is sponsored by Chinese High Technology Development Program since early 2008. Research of the key techniques such as the dual polarized antenna array, light weight receiver and digital correlator has completed. System integration is finished by November 2009. A series of tests had been finished to make sure that every subsystem works fine. Ground and truck based imaging tests will conduct in a couple of months. An opportunity of flight test is being discussed. The fight test will focus on the vegetation and soil moisture over land by April 2010.

2. FPIR DEMONSTRATOR

The antenna array of classical 1D interferometer, such as ESTAR, LRR-X, and CAS C-band and X-band instruments, are comprised of single polarized waveguides. Therefore only single polarized radiation can be received by classical 1D interferometer. Because they use far less elements than that of 2D instrument, 1D interferometer has the advantage of light weight, low power and relatively simple electronics. However, single polarization radiometer is unable to be applied to retrieve polarimetric information. Some very important parameters, for instance the wind vector over ocean surface, are excluded from its applications.

FPIR system is designed to extend the capability of 1D interferometric radiometer. By introducing a dedicated dually polarized antenna array, FPIR is capable to measure polarimetric products. Two interlaced thinned arrays of orthogonal polarizations compose the FPIR antenna subsystem. Each of them is a complete 1D array that produces single polarized visibility samples at spatial frequency domain. By cross correlating the outputs of a pair of orthogonally polarized waveguides, cross polarized visibilities can be retrieved. Furthermore, we are exploring the possibility to build an element antenna with two orthogonal polarized feeds. This kind of element antenna will complement the absent cross correlation of the zero baseline of the interlaced array.

Another crucial parameter is the incident angle for polarimetric radiometer, typically around 50^{o}~60^{o}. Antenna beam of the classical 1D interferometer is of fan beam and nadir pointing. The incident angle of pixels varies between 0^{o} to 90^{o} from nadir pixel to the swath edge. FPIR makes the fan beam squint from the normal of the antenna surface thus result in a conical beam.

FPIR demonstrator is integrated by November 2009. It works at 10.67GHz with 11 MHz bandwidth. The demonstrator is comprised of 3 main subsystems: the interlaced array, compact receivers and digital correlator.

2.1. Antenna array

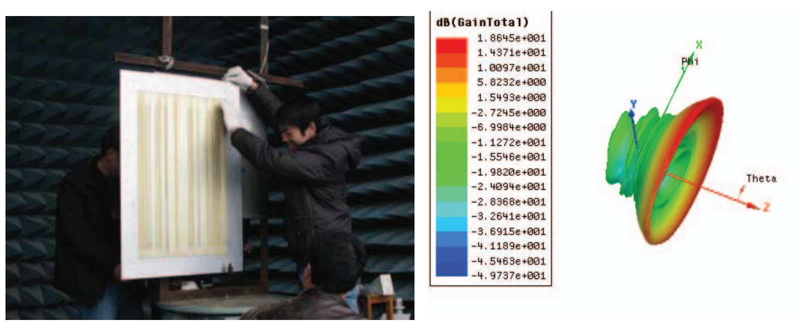

Fig.1 antenna array and 3D antenna pattern of single waveguide

9 waveguides of horizontal polarization and another 9 of vertical polarization form the antenna array of FPIR. 18 waveguides are embedded in a ground plane. The minimum spacing between adjacent waveguides is 0.635 wave length which is corresponding to 1000km swath from 800km orbit. Entire array is surrounded by ground plane. Gaps between waveguide antennas are filled with normal waveguides without slots. This configuration provides all waveguides consistent border environment to reduce the abnormality. The antenna patterns of the element waveguides are impacts by coupling thus result in ripples on the main beam. These effects can be compensated in signal processing software.

The waveguides are leaky wave antenna with vertical or horizontal slots for the orthogonal polarizations, respectively. 3D antenna pattern of single element, looks like a cap, is depicted in Fig.1.

2.1. Compact receivers

In order to reduce the mass and power, only 9 receivers are included in the demonstrator. Each receiver is connected to two waveguides through a coaxial switch. Following a special switching sequence, the receiver amplifies V and H polarized radiation sequentially. The switching sequence guarantees the capability of polarimetric measurement with single channel receiver.

The coaxial switch in front of each receiver has 5 branches. Two of them are connected to two waveguides with different polarizations; the third to a matched load; the fourth to a common noise source via 1-to-9 divider; the last to a cold sky pointing horn through an additional 1-to-9 switch. This complex switching system helps to calibrate receiver uncertainty, imbalance and interference between receivers.

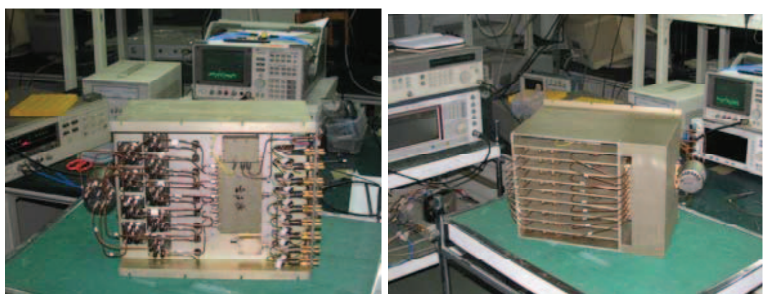

Fig.2 FPIR receiver

The receivers are single side band configuration. The received radiation is amplified with a LNA. A cavity band pass filter attenuates image frequency to -80dB. A mixer transits the RF signal to 340MHz intermediate frequency with synchronous 10.35GHz first local oscillator. Digital attenuator follows the IF amplifier. Second local oscillator at 350MHz passes a 1-to-9 divider and 9 phase shifters to all receivers. The phase shifters make it convenient for channel balance adjustment. The IF signals are further mixed to the IQ baseband of 5~15MHz.

2.1. Digital correlator

The digital correlator is based on commercial FPGA chip. Maximum 20 analog inputs are compatible for analog to digital converting and correlation processing. The ADCs convert the baseband signals at 8bit resolution. DC bias is detected with an accumulator at each channel. 45 correlations, including 36 cross correlations and 9 autocorrelations, are produced and uploaded to the computer via USB connection. A control and display software is developed to diagnose instrument performance. Magnitude and phase imbalance can be displayed in real time and adjustable by the control software.

3. FPIR PERFORMANCE

The demonstrator has been integrated and tested inside our laboratory. The imbalance between channels is within 0.3dB and 1 degree, respectively. Point source response is computed and presented in Fig.3. A series of ground based tests will be deployed in the following month to determine the instrument characteristics.

Truck based imaging test will be conducted early next year in order to acquire lengthy image. Flight test is scheduled for performance validation and application study, possibly by Apr. 2010.

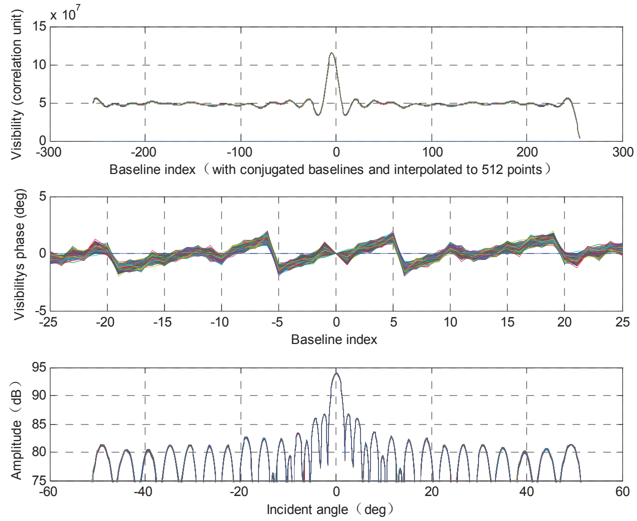

Fig 3 Retrieved image of point source

4. SUMMARY

FPIR demonstrator is presented. The demonstrator is comprised of 18 conical beam waveguides at orthogonal polarizations. Single receiver channel is switched to two polarizations with a special sequence. Receiver structure and digital correlator is described. Point source response is presented. Ground, truck and air based images are supposed to be attained by first half of 2010.

5. REFERENCES

[1] Jingye Yan; Ji Wu; Manuel Martin-Neira., "FPIR: A one dimensional full polarization interferometric radiometer," *Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007. IEEE International* , vol., no., pp.4408-4411, 23-28 July 2007.

[2] Le Vine, D.M.; Griffis, A.J.; Swift, C.T.; Jackson, T.J., "ESTAR: a synthetic aperture microwave radiometer for remote sensing applications," *Proceedings of the IEEE* , vol.82, no.12, pp.1787-1801, Dec 1994.

[3] M. Martin-Neira and J.M.Goutoule, “MIRAS: A twodimensional aperture-synthesis radiometer for soil moisture and ocean salinity observations”, *ESA Bulletin*, No.92, pp.95-104, Nov. 1997.