# Broadband polarimetric Microstrip Antennas for Space-borne SAR

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**Abstract**

A novel phased array antenna system for space-borne polarimetric SAR is proposed and completed in this paper. The antenna system assures polarimetric and multi-mode capability of SAR. It has broadband, high polarization isolation and high port to port isolation. The antenna system is composed of broadband polarimetric microstrip antenna, T/R modules and multifunction beam controller unit. The polarimetric microstrip antenna has more than 100MHz bandwidth at L-band with -30dB polarization isolation and high port to port isolation. The microstrip element and T/R module's structure and characteristics, the subarray's performances measuring results are presented in detail in this paper. A design scheme on beam controller of the phased array antenna is also proposed and completed, which is based on Digital Signal Processing (DSP) chip –TMS320F206. This beam controller unit has small size and high reliability compared with general beam controller. In addition, the multifunction beam controller unit can acquire and then send the T/R module's working states to detection system in real time.

**Key words**:

Antenna, Phased array antenna, Microstrip antenna, Polarimetric SAR, Space-borne SAR.

## 1. Introduction

Space-borne SAR that has all weather and round–the-clock survey capability is the main method of microwave imaging remote sensing. Space-borne multi-polarization SAR can get more information of the earth surface and became the main tendency of microwave remote sensing. The space-borne multi-polarization SAR needs to get the four kinds of polarization information i.e. HH, VV, HV and VH. Thus for radar antenna system, two orthogonal polarization channels are required which both have the abilities of receiving simultaneously and the function of transmitting alternately by switching. The antenna's polarization character is an important parameter influencing the performance of multi-polarization SAR. It is required that the polarization isolation and ports isolation of two orthogonal polarization antenna are both more than 30dB in general. In order to achieve multi-mode operations, the 2-D beam control function for the antenna is also required. An L-band broadband polarimetric microstrip antenna and its control unit- a multifunction beam controller is proposed and completed in this paper.

## 2. Requirement of SAR system and key techniques

For a space-borne L-band multi-polarization SAR system with high resolution, except the requirement of polarization, the main requirements for antenna system are:

- Bandwidth >100MHz
- Size of antenna: 9m×3.4m
- Range of incidence angle : 18~52 degree
- Polarization isolation: >30dB
- Port isolation: >30dB

The antenna of L-band multi-polarization SAR system that meets the above requirements can be accomplish conveniently using plane phased arrays. In order to reduce the size of the antenna system, it is reasonable to adopt the antenna element with dual-polarization to achieve multi-polarization performance. In this antenna system, the active phased array antenna is made up of the microstrip dual-polarization patch radiating elements.

There are three main technology difficulties to design the antenna system; the first one is large bandwidth. In general the bandwidth of microstrip antenna is measured with input voltage stationary wave ratio (VSWR) ≤2.0. If the bandwidth is 5.28% with the VSWR≤1.5, the bandwidth will be more than 12.% with the VSWR≤2.0. Traditional microstrip antenna is syntonic antenna, it's bandwidth is very narrow, only about 3%. The bandwidth of traveling wave microstrip antenna can meet the requirement but the gain can not. The second one is polarimetric technique. There are many methods to achieve coplanar dual-polarization performance that can be selected according to the special requirements. It is difficulty to achieve that polarization isolation is more than 30dB. The last one is high port isolation.

## 3. Broadband polarimetric microstrip antenna

### 3.1 Constituents of the antenna system

There are two feeding networks, horizontal-polarization network and vertical-polarization network, in the two-channel time-division multi-polarization SAR system. For the antenna of the SAR system, 5 sub-arrays are adapted along the azimuth. For each sub-array, every row consists of 8 radiating elements and there are 20 rows in the sub-array, those are connected with 20 T/R module components respectively. The sub-arrays and T/R module components form the phased array antenna sub-systems together. There are 100 T/R module components in the whole antenna constructing the 2-D phased array antenna system.

### 3.2 Broadband micro-strip antenna patch's configuration

Fig.1 shows the typical aperture coupling microstrip antenna that is a multi-layers structure. In this antenna, radiation patch is printed on the inner surface of the antenna cover(the antenna cover thickness:$h_2$ ) which located over the substrate (the thickness: $h_1$)with microstrip feeding line. There is a ground plane with rectangle gap through which microstrip line feeds power to the radiation patch.

It is found that the gap sizes in ground plane will control the coupling between microstrip feeding line and radiation patch. The bigger the aperture size is, the deeper the coupling is and the higher the efficiency is. The narrow gap excites less cross polarization but has narrow bandwidth. And the wide gap has wide bandwidth but produces more cross polarization. Inductivity between layers, space and the length of open microwave line are relative closely with impedance matching and bandwidth.

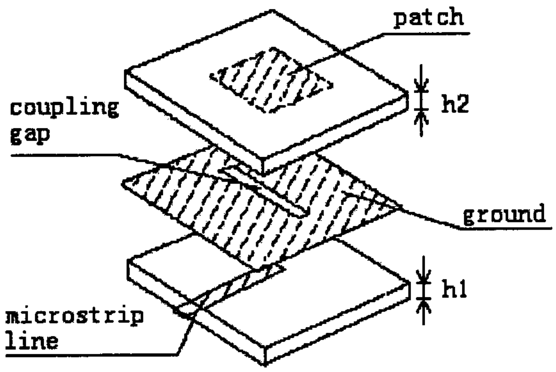
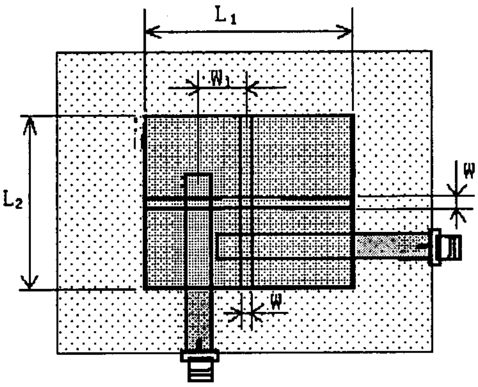



Figure 1 Structure of aperture coupling microstrip antenna element

Dual-polarization gap coupling microstrip antenna element is shown in Fig.2.



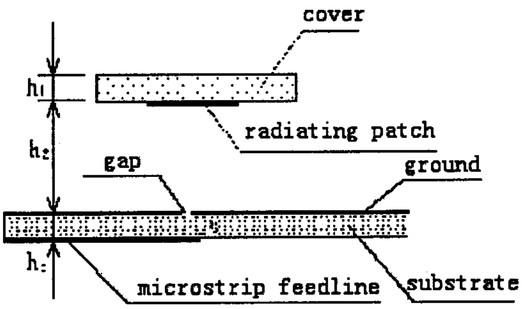




Figure 2 Structure of Dual-polarization gap coupling microstrip antenna element

### 3.3 Architecture of Dual-polarization antenna sub-array

Space between element should be as possible as wide in case of no spurious lobe existing so as to reduce cross coupling. When considering antenna sizes, side-lobe level, beam width, gain, etc. the antenna array is designed as follows.

The antenna caliber size is 1.6m×3.4m including 8×20 elements. Eight elements with interval $0.73\lambda_0$ are arranged in 1.6m to form a row and twenty rows are planned in 3.4m to form a line-array which is supplied with an additional power divider. The structure is shown in Fig.3. The line-array with twenty rows should achieve beam steering in ±20°, the space between elements is decided by Equ.1,

$$d \le \frac{n-1}{n(1+|\cos\theta_M|)}\lambda_0 \qquad (1)$$

When the antenna array feeds with equal-amplitude and in-phase, the highest side- lobe of the pattern is about –13.2 dB. The typical pattern is shown in Fig.4. As a result of feeding error, it can not be realized usually.

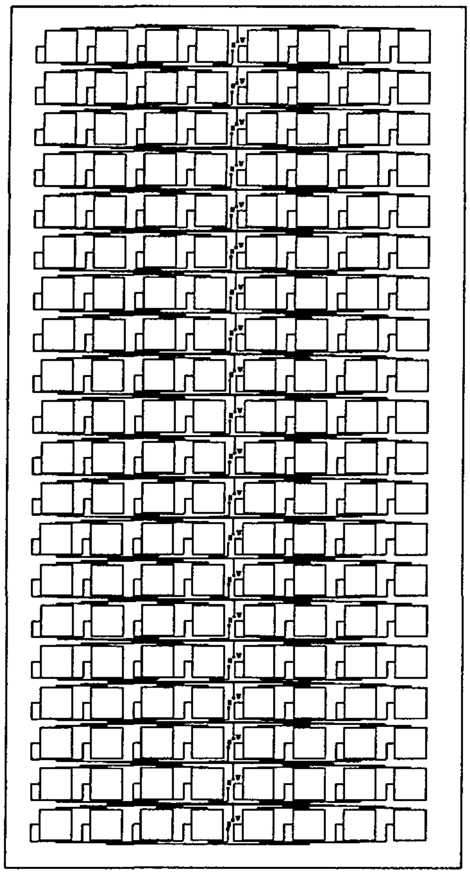


Figure 3 Dual-polarization antenna sub-array layout

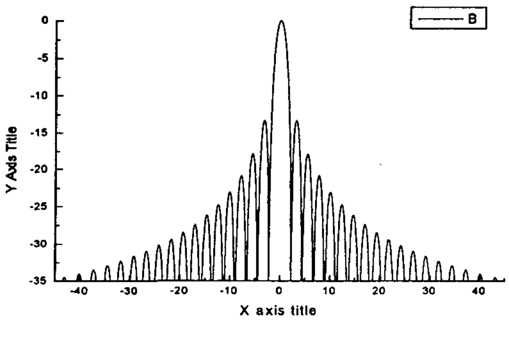



Figure 4 Typical pattern of antenna array with equal-amplitude and in-phase feeding

## 4 T/R module

In feeding network, there are many kinds of schemes in designing T/R module. The scheme of the T/R module with low power polarization switch is shown in Fig.5 In this scheme the transmitting channel is public. But there is one horizontal channel and one vertical channel in receiver so that receiving can proceed in the two channels at the same time. In this scheme the isolation between the two channels is large enough can meet the requirements of multi-polarization.

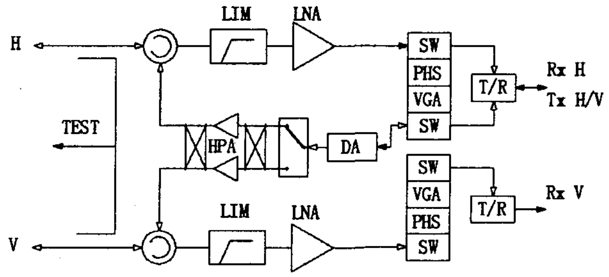



Figure 5 T/R module with dual-polarization channels

## 5 Beam controlling unit

The beam controlling unit is composed of controlling circuits, driver circuits and phase data acquiring cicuits. The Scheme of beam controller and its interface is shown on Fig.6.

The controlling circuits recieve commands by serial bus from monitor computer , then, the mode and beam number are translated. According to the mode, the controlling circuits change beam and phase code.

The driver circuits lies to the front of T/R module. The data of phase code is latched, decoded and enhanced by these circuits. In addition, the control signal is also provided for changing mode and T/R module.

Phase data acquiring cicuits acquire phase data from flip-latch situated at T/R module and transmit these data to DSP, DSP check every unit's status of antenna and modify the design of antenna pattern in time. The acquiring circuit is also used to validated the function of the beam controlling unit. The step is that DSP send "1" and "0" to every phase shifter of every T/R module, and check the output of acquiring circuits.

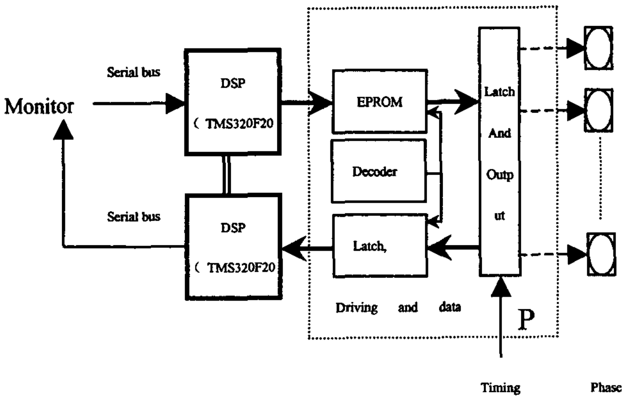
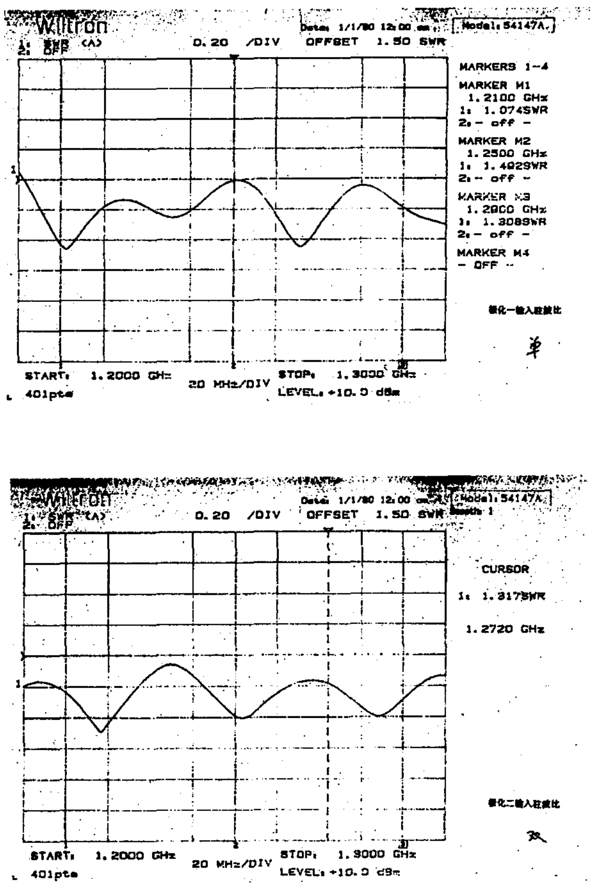



Figure 6 Scheme of beam controller and it's interface

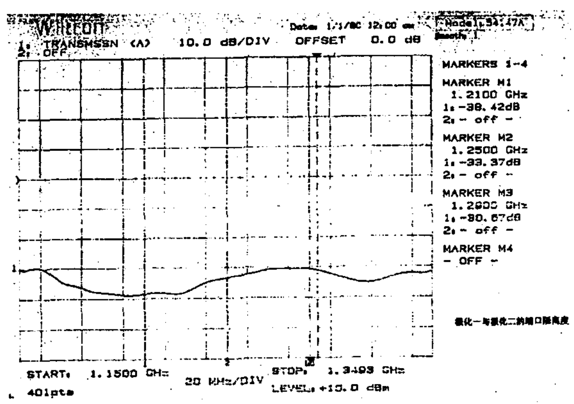
## 6 Measuring Result

### 6.1 VSWR and Isolation

The stationary wave characteristic and the isolation characteristic of the dual-polarization antenna sub-array are shown in Fig.7. It is shown VSWR is less or equal to 1.5 and the isolation between the two polarization ports exceeds 30.0dB。




(a) VSWR of the two channels

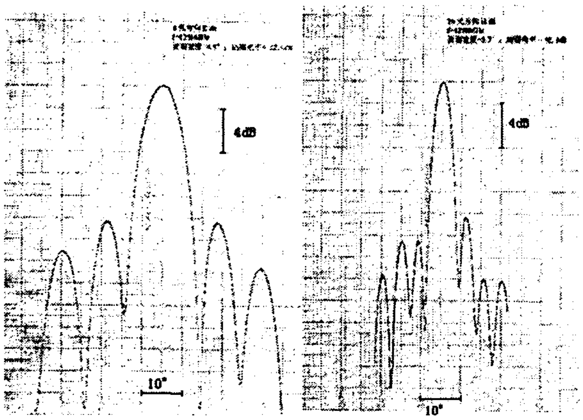



(b) Isolation between the two orthogonal polarimetric channels

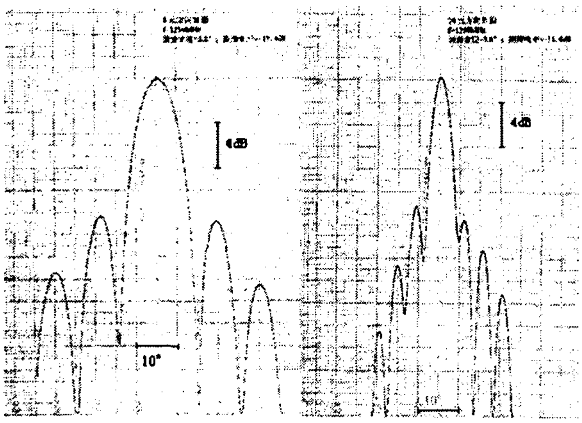
Fig.7 VSWR and isolation curves of the dual-polarization microstrip antenna array

### 6.2 Radiation Pattern

The directional patterns of dual-polarization antenna sub-array are shown in figure 8. In the figure 8, figure (a) and (c) are the patterns in azimuth, figure (b) and (d) are the patterns in range. Figure (a) and (b) are the patterns of horizontal polarization, in which side-lobe levels are less than −12.4dB. Figure (c) and (d) are the patterns of vertical polarization, in which side-lobe levels are less than −11.6dB.




(a) H-polarization (b) H-polarization




(c) V-polarization (d) V-polarization

Figure 8 Directional patterns of dual-polarization antenna sub-array

## 7 Conclusions

The antenna sub-array with 8×20 elements is designed, it's pattern, stationary wave and ports isolation can meet requirements. The port isolation is more than 30dB and the gain of antenna sub-array is more than 27dB. The sub-array frequency bandwidth is more than 100MHz, where the input voltage stationary wave rate is below 1.5.

The result shows that microstrip antenna with coupling feed has wider bandwidth and the bandwidth of single polarization element can reach 35%(VSWR≤2.0). Because the feed-line and radiation patch are not in the same plane (the feeding line is behind the floor so it isolates the feeding line from the radiation patch), the clutter radiation suppression and the polarization isolation is good.

## 8 References

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