Spaceborne phased array antenna for communication systems

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***Abstract*—In this paper, differences between the communication and radar systems, which will results in different requirements for the phased array antenna design, are analyzed firstly. Then the state of the art of on-orbit phased array antenna for the communication systems is introduced. Lastly, future development of phased array antenna is discussed based on the market demand and technology trends**

Keywords—spaceborne; phased array antenna; communication systems

I. INTRODUCTION

Phased array antennas are the very hot research topic in the modern antenna community and have been widely used in the different scenarios. It was firstly used for radar system in American since 1950s [1] and then widely used in the ground base radar system with the development of semiconductor technology.

However, it was seldom used in spaceborne equipments because of high cost and limited power that satellite platform can supply. While with the urgent demand of satellite communication payload with the features of higher capacity, smart beam forming and quasi real time area coverage with beam hopping, antennas with the characteristics of multi-beam, beam agility and on-orbit beam reconfigurable are preferred. At the same time, because the capacity of satellite platform are improved dramatically either, the phased array antenna is the best candidate and have been equipped in some launched satellites[2-4].

In this paper, we focused on spaceborne phased array antenna for communication systems. Different applications mean different requirements, so the differences between the communication and radar system, which will results in different requirements for the phased array antenna design, are introduced firstly. Then the state of the art of on-orbit phased array antenna for the communication systems is introduced. Lastly, future development of phased array antenna is discussed.

II. DIFFERENCES BETWEEN COMMUNICATION AND RADAR SYSTEMS

Five differences between the communication and radar systems especially for the satellite applications and their effects on the phased array antenna design are discussed in this part.

A. Operating mode

For the communication systems, the signals are continuous wave and they are often working at full-duplex mode, which means high isolation between the transmit and receive antenna are required, so the transmit and receive antennas are always distributed separately for the purpose of high isolation. While for the radar system, impulse wave and half-duplex is preferred, so transmit-receive sharing antenna technology is the traditional design.

B. Antenna polarization

For the satellite communication system, circular polarization is preferred because of far less fading and flutter. While for radar system, linear polarization is always employed because of the simple design.

C. Working mode of power amplifier

For the communication system, because the transmitted signals are always have the features of wideband and multi carrier frequency, power amplifier are required to working at linear area especially for the higher modulation technology. While for radar system, transmitted signals is narrowband in most cases, so power amplifier are always working at saturation area for the purpose of high efficiency.

D. Gain issue of thinned/sparse array technology

For the communication system, high gain means higher transmission data rate. So the thinned or sparse array technology is seldom used because of dramatically gain reduction, which will results in large power consumption. While for radar system, narrow beam width for high resolution is preferred, so the thinned or sparse array technology is widely used to reduce the channel number of phased array antenna and save the cost of radar system.

E. Gain of edge of coverage(EOC)

For the communication system, antenna beam is required to cover the specified area, while higher peak gain means narrower beamwidth, so there is a compromise between the antenna gain and beamwidth , so the best element size (inter-space of antenna array) should be chosen to realize the optimal array distribution[5], as shown in Fig.1.

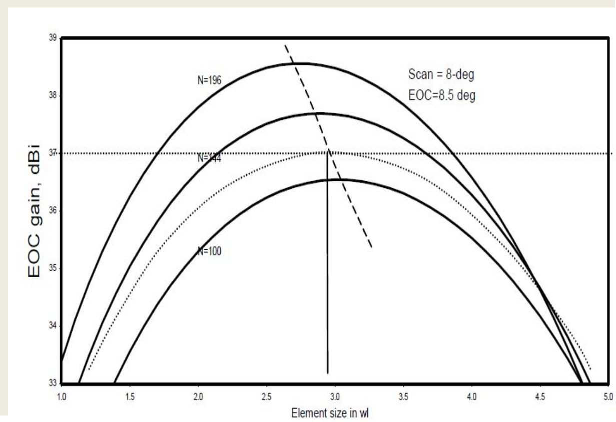

Fig. 1. Best EOC curve with horn antenna

III. TYPICAL ON-ORBIT PHASED ARRAY ANTENNA FOR COMMUNICATION SYSTEMS

Three typical on-orbit phased array antennas that represents the state of the art of the phased array antenna for communication systems in the open literatures are introduced in this part.

A. *Wideband Inter-Networking engineering test and Demonstration Satellite`*

The first one is the Wideband Inter-Networking engineering test and Demonstration Satellite (Winds) [2] that is designed by Japan. One transmit and one receive multi-beam phased array antenna are equipped on this satellite, as shown in Fig.2. The main performances of phased array antenna are shown in Table I.

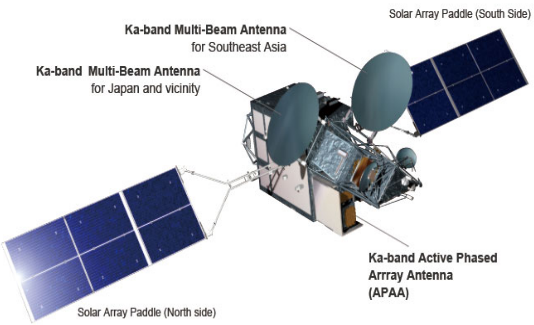

Fig. 2. Pictures of Winds

TABLE I. PERFORMANCES OF PHASED ARRAY ANTENNA ON WINDS

No.	*Item*	*Performance*
1.	Working frequecy	Tx: 30GHz Rx:20 GHz
2.	Beam No.	Tx:2 Rx:2
3.	Field of view	Azimuth:8° Elevation:7°
4.	AEIRP	≥54.6 dBW
5.	G/T	≥7.1 dB/K

B. *Wideband Gapfiller Satellite*

The second one is Wideband Gapfiller Satellite (WGS) [3] that is designed by American. One transmit and one receive multi-beam phased array antenna are placed on this satellite either, as shown in Fig.3. The main performances of phased array antenna are shown in table II.

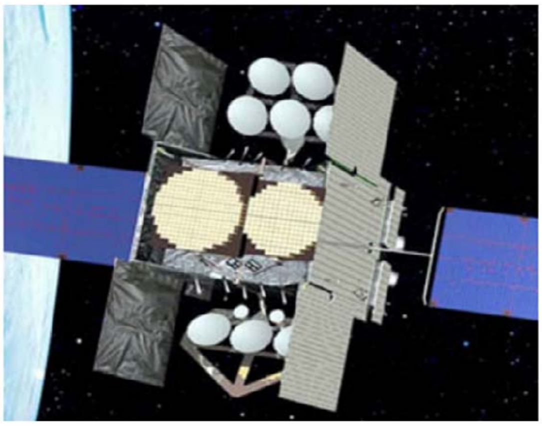

Fig. 3. Picture of WGS

TABLE II. PERFORMANCES OF PHASED ARRAY ANTENNA ON WGS

No.	*Item*	*Performance*
1.	Working frequecy	Tx: 7.250~7.672GHz Rx:7.978~8.4 GHz
2.	Beam No.	Tx:8 Rx:8
3.	Field of view	± 8° conical angle
4.	AEIRP	≥60.8 dBW
5.	G/T	≥6 dB/K

C. *Advanced Extreme High Frequency*

The third one is Advanced Extreme High Frequency (AEHF) [4] that is also designed by American. Two transmit and one receive multi-beam phased array antennas are equipped on this satellite, as shown in Fig.4. The main performances of phased array antenna are shown in table III.

Fig. 4. Picture of AEHF

TABLE III. PERFORMANCES OF PHASED ARRAY ANTENNA ON AEHF

No.	*Item*	*Performance*
1.	Working frequecy	Tx: 20GHz Rx:44 GHz
2.	Beam No.	Tx:2 Rx:4
3.	Field of view	± 8° conical angle
4.	AEIRP	/
5.	G/T	/

IV. FUTURE DEVELOPMENT OF PHASED ARRAY ANTENNA

With the development of MMIC, LTCC and HDI technology, highly integrated active phased array antenna (HIAPAA) will be widely used in space application [6]. According to the market demand analysis and the technology development of phased array antenna, phased array antenna with multi-beam and higher frequency denotes the future trends.

A. Multi-beam for multi-objectives and high capacity

To communicate with multi-objectives at the same time and increase the capacity of the satellite, phased array antennas with multi-beam need to be developed. However, digital beam forming (DBF) suffers high power consumption and limited bandwidth, while analog beam forming (ABF) suffers limited beam number. So multi-beam phased array antennas with reasonable beam forming technology need to be further studied. In addition, power amplifier linearity issue for transmit multi-beam antenna are also need to be addressed.

B. Higher frequency for high capacity and anti-jam

By operating at higher frequency, more signal bandwidth can be obtained, so higher capacity can be achieved. At the same time, because narrower beamwidth and large path loss can be easily formed in the higher frequency, Anti-jam for received antenna can be realized easily. Lastly, higher frequency such as terahertz band is a transition between the mm-wave and laser light.

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