Int. J. Electron. Commun. (AEÜ) xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

ELSEVIER

Regular Paper

Design of a compact multilayer circularly polarized phased array transmit antenna system for satellite applications

Elham Sharifi Moghaddam *

Satellite Research Institute, Iranian Space Research Center, Iran

ARTICLE INFO

Article history:
Received 8 September 2015
Accepted 21 May 2016
Available online xxxx

Keywords:
Phased array antenna
Multilayer
Circular polarization
Active antenna
Satellite
Genetic algorithm

ABSTRACT

An active phased array antenna which can scan its beam direction to a wide range of scan angles is presented in this paper. The paper proposes a new technique to compact a phased array antenna and making it suitable for applying in satellite payloads. This antenna should transmit high data rate signal from satellite to ground stations; and by spatial power combining the needed Effective Isotropic Radiated Power (EIRP) for the transmission link will be provided. The main beam can be scanned to 50° from normal. Polarization of the radiated wave of this antenna is circular. The designed antenna benefits from microstrip technology and has a unique low mass multilayer structure with two different substrates. For implementing antenna's RF circuits, Microwave Monolithic Integrated Circuits (MMICs) have been used and they are integrated expertly with microstrip radiators. Beam controller board sends necessary commands to MMICs for setting phase and amplitude of each array module. For decreasing side lobe level in high scan angles, genetic algorithm is applied and excitations of array elements are optimized. Design stages and simulation results of the array antenna are summarized in this paper and the results are compared with test results.

1. Introduction

In present article an antenna for the payload of a Low Earth Orbit (LEO) remote sensing satellite, which should transmit high data rate signal to the receive ground station is designed. The requirements of this satellite antenna are: (1) Providing necessary EIRP for satisfying link budget needs; (2) Low electrical power consumption; (3) Low mass and size.

For decreasing electrical power consumption, the output radiated power should be reduced. So regarding to the satellite requirements, for providing necessary EIRP which is assigned by link budget calculations, the antenna pattern should be directive. Since a LEO satellite position in relation to its ground station changes continuously, beam direction of the satellite antenna should track the ground station.

A phased array antenna which can scan its beam direction electronically is a suitable substitute for a mechanically scanning beam antenna for satellite applications, because it has lower mass and construction cost; and also eliminates torque disturbances that moving parts may apply to the satellite structure.

An active antenna module which is suitable for use in large phased arrays has been proposed in [1]. It has a three layer packaging structure which is composed of two different substrates and is fabricated in a ball-grid array package. This package can be easily mounted on the mother board of a phased array system. This antenna module comprises a microstrip patch antenna which has been implemented on the top side of the structure, MMICs and passive devices which has been mounted on the underside of the antenna. This module is a transmit/receive antenna with dual polarization for half duplex operation and uses a low noise amplifier and a power amplifier for providing gain in receive and transmit modes.

Design and implementation of a phased array antenna driver which can adjust phase and magnitude of modules in an array is discussed in [2]. Each single driver includes a 5-bit digital attenuator, a 0–180° voltage variable phase shifter and a feed-back loop for calibrating the driver and tracking the phases and magnitudes of its outputs accurately. The settings are fully computer controlled via the bi-directional Serial Data (SDA) and Serial Clock Lines (SCL) of an Inter Integrated Circuit (I2C) communication bus. The designed driver in this paper is applied to a 1 GHz 4×4 array. The implemented antenna by employing this driver uses brick architecture [3], so it engages large amount of space. Nevertheless proposed driver is reliable, low cost, and can be applied to any

* Address: No. 74, 14th Str., Saadat abad blvd., Tehran, Iran.
E-mail address: telecom@sri.ac.ir

http://dx.doi.org/10.1016/j.aeue.2016.05.011
1434-8411/

$N \times M$ array and higher frequency designs. Furthermore phased array antennas have application in pulse compression radars (PCR). In [4] a PCR with a reconfigurable signal processor and millimeter-wave phased array antenna is designed.

Phased array antennas are used in *Q*-band satellite communication, also. In [5] a transceiver circuit for a bidirectional phased array is presented. This circuit benefits from a novel bidirectional amplifier (PALNA) that eliminates the need for microwave switches before and after the low-noise amplifier and power amplifier. The input of the low-noise amplifier and the output of power amplifier are connected through an isolation network. To operate in either receive or transmit mode, the base biasing is adjusted. The Q-band bidirectional transceiver consists of an integrated PALNA, passive ring mixer, frequency doubler with a LO amplifier, and IF amplifiers implemented in a 0.12-μm SiGe BiCMOS process.

For a satellite antenna, satellite system requirements determine main specifications of the antenna. Parameters like satellite altitude, operational frequency of the communication payload, and data size which should be transmitted during each access time of the satellite are inputs to the link budget calculations. Restrictions of the satellite in available mass and space for the satellite payload also specify the maximum mass and dimension of the antenna. As previously discussed, constraints in electrical power supply in the satellite, regarding to its limited size of solar panels, oblige designers to use directive antenna in the payload of remote sensing satellite with real time communication.

In this paper, the desired phased array antenna should scan its main beam direction in the range of $-50°$ to $50°$ from bore-sight in all azimuth angles in the space. The central frequency of this antenna is 8.2 GHz and its bandwidth is 200 MHz (2.4%). The minimum EIRP of the antenna must be 40 dBm, and at least 30 dBm power should be radiated from the array antenna in order to satellite power limitations. The antenna gain in maximum scan angle must be minimum 10 dBi; and it should radiate with circular polarization. For preventing Faraday rotation effect, and decreasing polarization loss, circular polarization is preferred for this antenna.

Each module of the array must have a power amplifier that provides the needed output power of each module and after spatial power combining, the output power magnifies to the desired amount of 30 dBm.

Novel design and implementation approach which is proposed in this article, leads to smaller size and mass in comparison with other phased array architectures, and makes it appropriate for mounting on a satellite body.

In present article, design aspects of a phased array antenna with above mentioned specifications are described and simulation results are investigated. The design fundamentally includes determining the number of elements, choice of radiating elements, calculating the elements spacing, selection of lattice, and configuration of the array elements and microwave devices that would yield the desired EIRP while satisfying other constraints like mass and construction cost. In addition, the array is optimized by genetic algorithm (GA) for decreasing side lobe level (SLL) in high scan angles while keeping beam-width in an acceptable domain. Finally test results of the constructed antenna are presented and compared with simulation results.

2. Antenna block diagram

Antenna system consists of a phased array antenna board and a beam controller board. The phased array antenna board is an array of 4×4 modules. Fig. 1 shows block diagram of the designed antenna. Each module comprises of a radiating element, a power

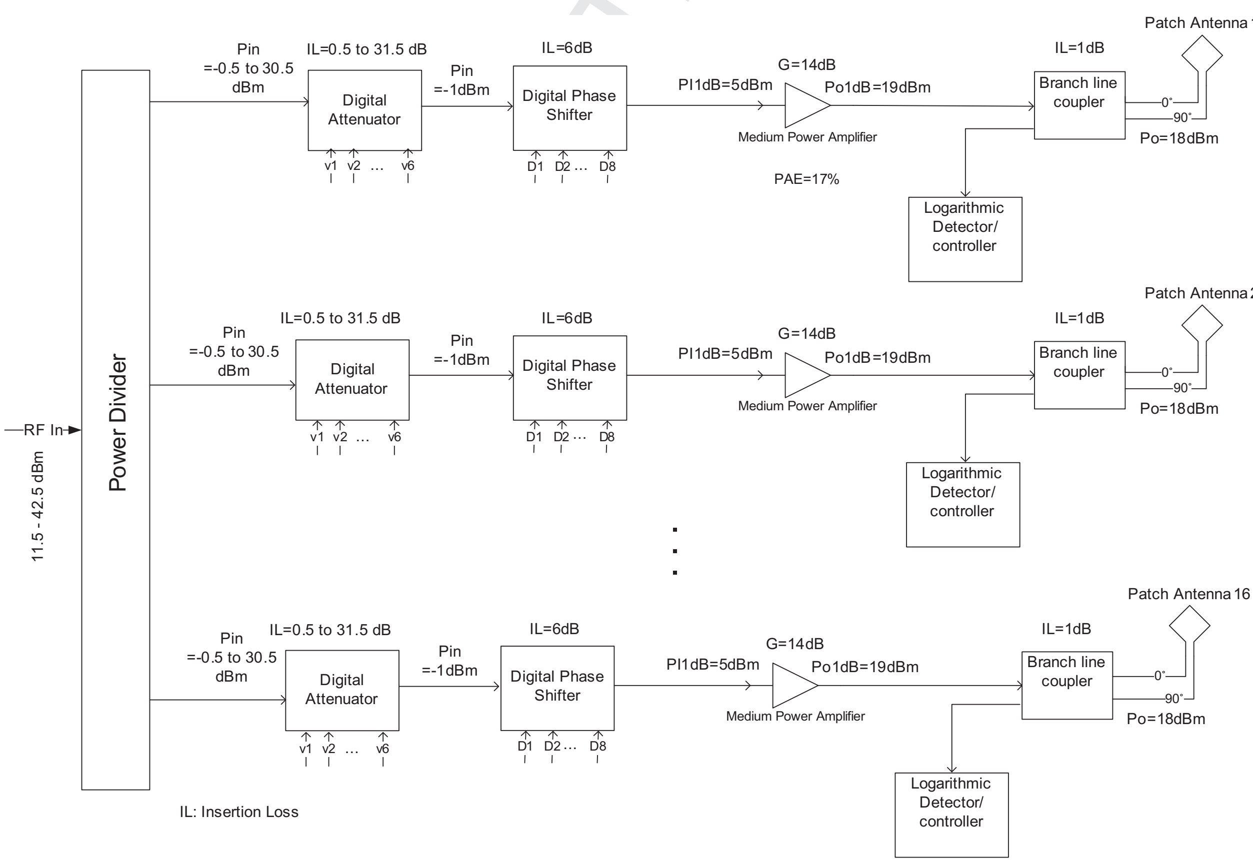

Fig. 1. Block diagram of designed phased array antenna.

Please cite this article in press as: Moghaddam ES. Design of a compact multilayer circularly polarized phased array transmit antenna system for satellite applications. Int J Electron Commun (AEÜ) (2016), http://dx.doi.org/10.1016/j.aeue.2016.05.011