
Sudhakar Rao


Peter de Maagt


Rajeev Jyoti

Satellite Communication Antennas

Over the past two decades, there has been tremendous growth in satellites systems. These include satellites for commercial, military, navigation, and science missions that are launched and deployed in highly elliptical orbit, geostationary (GEO), medium-Earth orbit, low-Earth orbit (LEO), deep-space, and remote sensing applications. Antenna systems for these satellites are critical parts of the payloads providing downlinks (satellite to ground) with required effective isotropic radiated power and uplinks (ground to satellite) with minimum gain to noise temperature values. The antennas for each mission are unique and can be classified into high-, medium-, and low-gain systems, with all three required for most satellites to provide communications through main mission on-orbit, global coverage on-orbit, and telemetry and telecommand during transfer orbit as well as on-orbit. Typical applications include

- high-throughput satellites (HTSs) or personal communications satellites
- direct-to-home satellites
- global positioning satellites
- fixed-, broadcast-, and mobile satellite services
- protected tactical satellites
- deep-space missions
- remote sensing satellites.

Antenna designs for these systems include mostly reflector antennas, phased arrays, horn antennas, biconical antennas, and less frequently reflectarrays and lens antennas. The coverage scenarios vary, including wide global coverage, contoured national coverage for domestic satellites, weighted national coverage to compensate for atmospheric attenuation at higher frequencies, high-gain spot beam or multiple spot beam coverage, and omnidirectional coverage. Beam reconfigurability on-orbit is an important aspect of military satellites, while enhancing the satellite capacity is key to commercial satellites such as HTSs, and low-cost, high-volume payloads are the main focus for the LEO constellation of satellites where tens of thousands of satellites are planned to be launched in the next decade by Amazon, SpaceX, O3B, and several other operators.

This special issue of *IEEE Antennas and Propagation Magazine* focuses on recent advances in satellite communication antennas.

This special issue of *IEEE Antennas and Propagation Magazine* focuses on recent advances in satellite communication antennas. Several authors submitted advanced antenna development aspects related to satellite payloads covering recent trends in technology, small satellites (smallsats), low-cost antennas for large-volume production, phased arrays, reconfigurable antennas, reflector/reflectarrays, and novel measurement techniques. Based on a rigorous review process, 11 articles have been selected covering recent trends and developments in satellite antennas for inclusion in this special issue. A few accepted articles that were not chosen to appear in this special issue due to page constraints will appear in future issues of the magazine. The articles in this special issue include generic payloads for future satellite communications that combine antenna systems with digital payloads; a review of CubeSat antennas from LEO to deep-space applications; higher-volume and low-cost antennas using design for manufacturing, assembly, integration, and test (DFMAIT); antenna designs for new space; development aspects of aperiodic constrained lens antennas and reflectarrays for multiple beam applications; advances in reflector-shaping technology; reconfigurable reflector antenna technologies for wide-scan and high-performance applications; large patch arrays with significant cross-polarization improvements for telemetry applications; sparse array development for synthetic aperture radar (SAR) applications; and advanced measurement techniques for HTSs using a compact range facility.

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ANTENNAS WITH DIGITAL PAYLOADS ARE THE FUTURE

In "Satellite Antennas and Digital Payloads for Future Communication Satellites," Fenech et al. discuss the future trends in satellite communication payloads, where antennas with digital back ends are used instead of bent-pipe transponders to provide flexibility to cope with changing operational requirements during the life of the satellite. A digital payload concept providing in-built flexibility of frequency allocation and location of beams for LEO and GEO satellites is described. The technical challenges, cost impacts, and flexibility associated with digital payloads are given in this article with a brief discussion on the Eutelsat Quantum program, which is the first software-defined commercial satellite at Ku band.

The second article, "A Reconfigurable Reflector Antenna System With a Hybrid Scanning Method" by Rao et al., describes the development of a dual-band Ka/extremely high-frequency reconfigurable payload with high-gain spot beams and large coverage beams using digital beamforming and imaging reflector antennas. Beam scanning is achieved using a combination of electronic scanning over a small region and reflector gimbaling over a large scan region, such as global coverage, and by using a cost-effective smaller feed array. Recent developments of global positioning satellites using a dual-reflector imaging antenna and a seven-element triplexed feed array using a digital beamforming network have been described.

REVIEW OF CubeSat AND SMALLSAT ANTENNAS

"Advanced CubeSat Antennas for Deep Space and Earth Science Missions," by Chahat et al. gives a comprehensive overview of antennas for CubeSats and smallsats from LEO to deep-space satellite communications. The first use of CubeSats for deep-space communication through the development of MarCO and RainCube missions by NASA/Jet Propulsion Laboratory is described in this article. Also, recent developments related to low-, medium-, and high-gain antennas using low-cost designs at UHF, S, X, Ku, and Ka bands are given. Technical advancements related to mesh reflector antennas and Si/GaAs metasurface antennas are highlighted.

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HIGH-VOLUME, LOW-COST SATELLITE ANTENNAS

In the recent past, there has been an increased demand for constellations of satellites operating in nongeostationary orbits. Amazon, SpaceX, O3B, Iridium-Next, OneWeb, and other operators are planning thousands of such satellites in the LEO. In "Paving the Way for Higher-Volume Cost-Effective Space Antennas," Glâtre et al. present low-cost antennas developed for these high-volume satellites using DFMAIT. Innovative steerable antenna designs, fastener-free feed chains, 3D-printed antennas, and automated assembly and test setups are highlighted in this article.

Venezia et al. explore antenna designs in "Feed Network Design Using NewSpace Techniques." *NewSpace* is a term that has been used recently to describe a new methodology for modern space ventures. Significant size and mass reductions can be achieved using new space methodologies. Examples of reflectors and feed networks employing NewSpace technology are described.

MULTIPLE BEAM ANTENNAS DESIGN AND TEST

In "A Ka-Band Active Aperiodic Constrained Lens Antenna for Multibeam Applications," Ruggerini et al. consider an active Ka-band aperiodic constrained-lens antenna for multiple beam applications using a single aperture instead of conventional multiple apertures. Wide-bandwidth capability and low scan loss performance of the Ka-band active lens have been described. Mass, spacecraft accommodation, and thermal issues still need to be resolved.

Mishra et al. introduce multiple spot beam antennas and payload characterization of HTSs in "High-Throughput Satellite Characterization." The innovative measurement technique has been successfully implemented by the Indian Space Research Organisation on multiple satellites, and this method seems to reduce the measurement time by about 70%.

In "Advanced Multibeam Antenna Configurations Based on Reflectarrays," Martinez-de-Rioja et al. review multiple beam antenna configurations at K/Ka bands using reflectarray designs. By using reflectarrays, the number of apertures is reduced from four (conventional) to two, offering advantages of cost and ease of accommodation on the spacecraft. Both single- and dual-reflectarray configurations have been explored, and results are provided.

SHAPED GREGORIAN MULTIBAND ANTENNA FOR FLY-AWAY SATCOM TERMINAL

A portable fly-away terminal for satellite communications supporting C-band and Ku-band frequencies is given by Gupta et al. in "Parallel-Shaping Technique for a Ring-Focus Reflector Antenna." It employs a multiband-shaped Gregorian antenna with ring focus. A common main reflector with swappable feed/subreflector is designed using a new shaping procedure. Results of shaped axially displaced ellipse are presented for a 1.8-m antenna in which the main reflector is made up of seven panels to reduce mass.

ARRAY ANTENNAS FOR SAR INSTRUMENT AND TELEMETRY APPLICATIONS

In "A Ka-Band Spaceborne Synthetic Aperture Radar Instrument," Bekers et al. review a sparse array design for a Ka-band spaceborne SAR instrument. The proposed SAR array is shown to reduce

the number of elements by 40% compared to a regular array with marginal reduction in performance. Thermal and spacecraft accommodation issues are discussed.

Kumar et al. demonstrate the design of a microstrip patch array for telemetry applications in "A Large Microstrip Patch Array With a Simplified Feed Network." An array feed network design to achieve low cross-polar isolation of better than 35 dB is given. Results of a 32-by-16 rectangular array at Ku band show better than 30-dB cross-polar isolation and low mass.

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AUTHOR INFORMATION

Sudhakar Rao (skraoks@yahoo.com) is a technical fellow at Northrop Grumman Aerospace Systems, Redondo Beach, California. His research interests include antenna systems for space, air, and ground applications. He is a Life Fellow of the IEEE.

Peter de Maagt (Peter.de.Maagt@esa.int) is the head of the Antenna and Submillimeter Section of the European Space Agency, Noordwijk, The Netherlands. His research interests include millimeter- and submillimeter-wave reflector and feed components, and electromagnetic bandgap antenna components. He is a Fellow of the IEEE.

Rajeev Jyoti (rajeevjyoti@hotmail.com) is an outstanding scientist and deputy director at the Space Applications Center, ISRO, Ahmedabad, India. He is a Senior Member of the IEEE and is the chair of the IEEE Antennas and Propagation/Microwave Theory and Techniques Gujarat Chapter in India.

PRESIDENT'S MESSAGE

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explore the possibility of coordination/collaboration with regional organizations related to antennas and propagation. On the other hand, we should think about people in North America for these years. The AP-S Meetings Committee and the Joint Meetings Committee have been handling such conference issues for many years. I would like to thank Prof. Roberto Graglia, chair of both committees, and the committee members for their tremendous hard work.

Today, it is necessary for us to cooperate with other relevant IEEE Societies to cover such advanced and diversified technical fields. Some of our conferences have actually been technically cosponsored by other Societies. We also have two journals jointly sponsored with other Societies. For this purpose, in 2016, a Sister Society Agreement was concluded among AP-S, the IEEE Microwave Theory and Techniques Society (MTT-S), and the IEEE Electromagnetic Compatibility Society (EMCS). The agreement was renewed in June 2019 (Figure 1). We will continue to promote our cooperation on membership development and various professional activities. The AP-S is planning to make similar agreements or memorandums of understanding with other IEEE Societies and non-IEEE organizations for better and extended service to our members. Your constructive comments and positive participation is more than welcome.

Finally, it was recently announced that our president-elect, Prof. Mahta Moghaddam, has been elected to the National Academy of Engineering (United States). I would like to take this opportunity to congratulate her for this important achievement.