

High-Gain, Broadband Radial Elliptical-Slot Array Antenna With Side-Lobe Mitigation for Low-Cost Satellite Communication Systems

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Abstract—This paper presents a high-gain and broadband radial elliptical-slot array (RESA) antenna with side-lobe mitigation technique for low-cost satellite communication systems. The aperture of the proposed slot array antenna comprises a set of orthogonal elliptical slots with monotonic slot length variation alongside the radius of the aperture. The design comprises radiating slotted top plate and bottom ground plate parallel to one another separated by an optimal distance of 5.25 mm which is 1.05λ . The design is back-fed using a disk-head radiator probe. The overall dimensions of the proposed slot array antenna with the air-gap taken into account are $300 \times 300 \times 5.75\text{ mm}^3$. Simulation results show that the proposed slot array antenna has a broadband operating frequency range from 45 GHz to 110 GHz and beyond, covering both V and W frequency bands with a fractional bandwidth of 88.8% . The peak gain of the proposed design is 35.6 dBi at 60 GHz . The array exhibits a maximum half-power beam width of 9.5° , a low sidelobe magnitude of -4.12 dBi and a overall simple design indicates its suitability for low-cost SATCOM (satellite communications) applications.

I. INTRODUCTION

A global effort to deliver an efficient on-the-move connectivity based communication strategy to onboard mobile platforms using satellites and other high-altitude platforms has been nudged by surging demand and reliance on bandwidth-hungry wireless devices and components. The crucial part of this communication strategy is an extremely effective front-end antenna design that can achieve high-gain, broadband operation with a focused radiating beam along the line of sight. Also, the antenna design should be suitable for low-cost mass production to serve a variety of mass markets. The early 1960s had seen the introduction of Kelly's radial line slot array (RLSA) antennas [1] and later in 1980's, by Ando *et al.*, which are renowned for their highly directed radiation characteristics which portrayed great potential for slot-array antennas for satellite application. [2]. Despite the fact that several recent prior works contributed antenna designs for various high-frequency applications [3]–[5], only a few works optimized the antenna design parameters to achieve a high gain, broad operational bandwidth, and low sidelobe magnitude.

In this work, we present an optimal design of radial elliptical-slot array antenna with high gain and broadband operation intended for low-cost satellite communication applications. The novelty of our work is that the elliptical shaped orthogonal slots are optimized and are incorporated on aperture conducting metal plate to mitigate the side low issues. In addition, an optimized air gap is utilized between

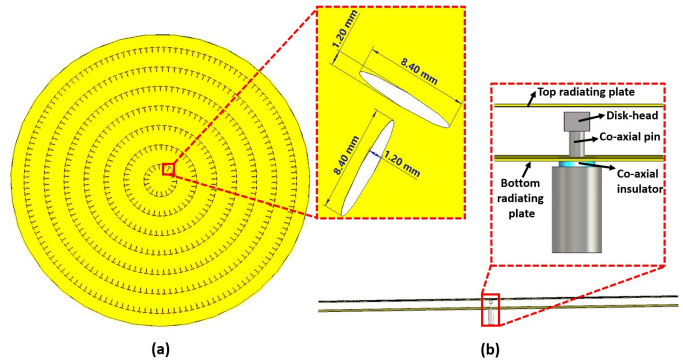


Fig. 1. The proposed slot array antenna (a) Top view (b) Side view.

top and bottom metal plates in order to achieve broadband operation and high gain.

The remainder of the paper is organized as follows: The antenna design methodology is presented in II. The simulation results of the proposed slot array antenna are discussed in III. Section IV provides the final remarks and future works.

II. ANTENNA DESIGN

The proposed radial elliptical-slot array (RESA) antenna is presented in Fig. 1. Fig. 1(a) shows the top view and Fig. 1(b) shows the side view. The design optimization and simulation are carried out using computer simulation technology (CST) suite. The design comprises of two metal plates parallel to one another with air gap in between to form a radial waveguide. The plate at the bottom behaves as ground plane and the one on the top which has slots incorporated behaves as radiating plate. Each of the orthogonal elliptical slot pairs (ESPs) function as unit radiator. The optimized ESPs are each designed with major-radius of 4.2 mm and minor-radius of 0.6 mm , which in terms of diameter is 8.4 mm and 1.2 mm , respectively. The ESPs are arranged along the varied concentric circular paths C_{P1} to C_{P7} across the aperture of radiating plate. The optimal radial distances of the individual circular paths starting from C_{P1} to C_{P7} from center of antenna aperture are 33.5 mm (6.7λ), 73.6 mm (14.7λ), 113.6 mm (22.7λ), 153.7 mm (30.8λ), and 193.7 mm (38.8λ), 233.8 mm (46.8λ), and 273.8 mm (54.8λ) correspondingly. The radial currents traveling outward within the waveguide are intercepted by the slots on the top plate and are responsible for mitigation of sidelobes. The point of feed is a middle section between the both plates.

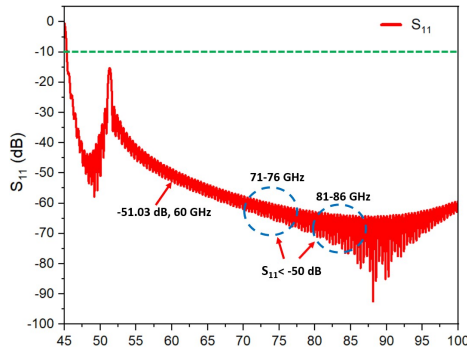


Fig. 2. S_{11} parameter result.

TABLE I
COMPARISON WITH OTHER WORKS

	[5]	[6]	[7]	This Work*
Gain (dBi)	44.6	36.9	21.5	35.6
Antenna diameter (mm)	900	405	175	300
Angular beamwidth	10°	9°	30°	9.5°
Sidelobe magnitude (dB)	-7	-10	-10	-4.12

* This work is based on simulation

The co-axial feed technique is used to excite the SMA at the center. The disk-head feed probe at the top end of SMA connector is responsible for symmetrical outward transverse electromagnetic (TEM) wave. The overall dimensions of the proposed slot array antenna with the air-gap taken into account are $300 \times 300 \times 5.75 \text{ mm}^3$. The optimal air-gap is estimated in the via parametric analysis.

III. RESULTS AND DISCUSSION

The simulated S_{11} parameter result is presented in Fig. 2. The magnitude value of S_{11} (in dB) is -51.03 dB at 60 GHz, and is less than -50 dB for the 71-76 GHz and 81-86 GHz which are specific bands within W-band, allocated by international telecommunication union (ITU) for satellite applications. The plots of directivity and gain versus the operating frequency are presented in Fig. 3. The maximum gain value of 35.6 dBi is observed at 60 GHz with side-lobe level of -4.12 dBi and angular beamwidth of 9.5°. The Fig. 4(a) presents the linearized 3D-view of the pattern and Fig. 4(b) shows the RHCP (right-hand circular polarization) and LHCP (left-hand circular polarization) plots at 60 GHz. Table I presents comparison of this work with prior works. This work showed better performance in terms of high-gain, broadband operation and low sidelobe level.

IV. CONCLUSION

A high gain, broadband disk-head ended SMA fed radial elliptical slot array antenna is presented that is suitable for low-cost SATCOM applications. The high gain value of 35.6 dBi with low-side magnitude of -4.12 dBi and a broad operational bandwidth covering V and W bands shows the best performance capability of the designed slot array antenna. As a

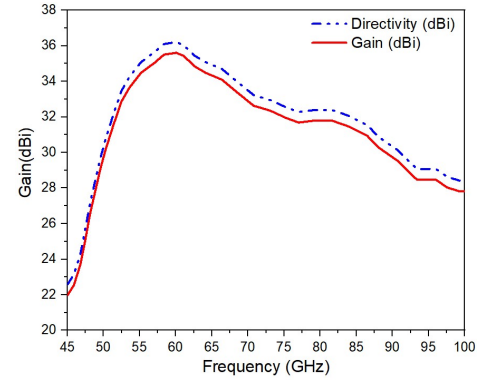


Fig. 3. Gain and directivity versus frequency plot.

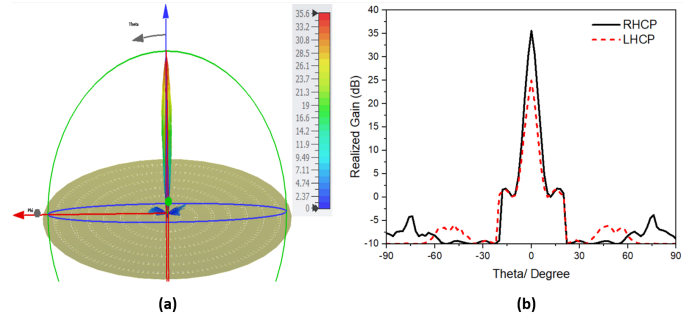


Fig. 4. Radiation pattern (a) linearized 3D-view (b) RHCP and LHCP plots.

future work, we plan to fabricate the proposed slot array design and the optimized disk-headed SMA to conduct a through analysis on simulated and measured results.

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