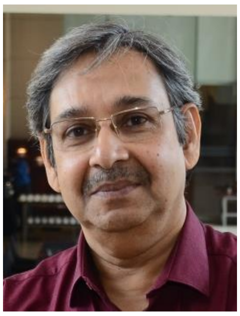
Executive Summary



Prof. Debatosh Guha
Professor, Institute of Radio Physics and Electronics
University of Calcutta

1. Title of the Project: **Development of Metasurface Enabled Multifunction Antennas for Medical and 5G Applications**

2. Date of Start of the Project: **1 February 2020**

3. Aims and Objectives:

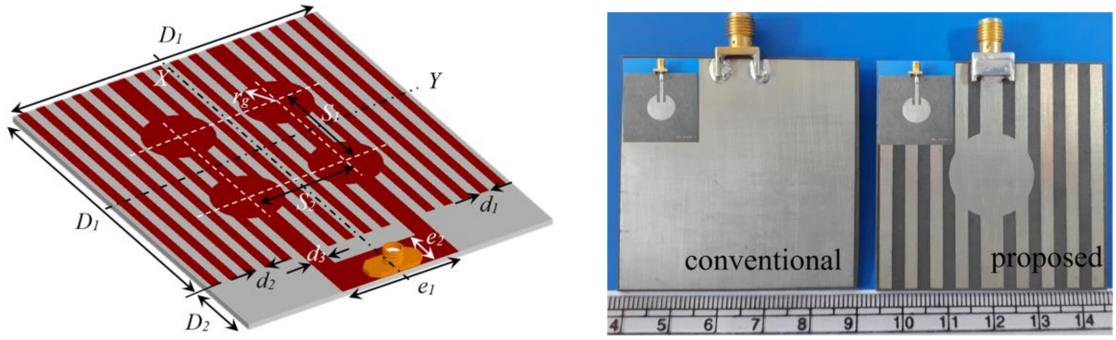
The work basically aims developing unconventional surface geometries such as the ground plane for printed antennas and also superstrate structures for realizing high gain resonance cavity radiators. The idea was to explore advantageous features which are challenging in the traditional geometries. They are basically for advanced communication front-ends and feed designs for industries and our national R&D laboratories. The primary novelty is focused to use the limited available area onboard in view of portable hardware management. The objective revolves around introduction of suitable geometries that result in advanced surface impedance or features. The objective of this project also includes developments of scientific basis of the designs based on thorough physical insight which would help in extending as well as translation of the technology for industrial applications.

4. Significant achievements (not more than 500 words to include List of patents, publications, prototype, deployment etc.)

The work has been targeted towards generating new technological concepts and insights applying to 5G communications. The results obtained so far have been featured in 13 articles published in IEEE Transactions and Letters. Our collaborative efforts and interactions with National Institutes and Industries (in the pandemic and post-pandemic restrictions of the last 3 years) have resulted in some novel antenna developments. A summary is provided below:

(i) New technique of Surface current control (to improve SAR characteristics):

Synthetic Aperture Radar (SAR) specifically demands high polarization purity for improved resolution. The longstanding challenge to achieve the same over the diagonal planes has been resolved by introducing a new cost-effective technique. This replaces the traditional ground

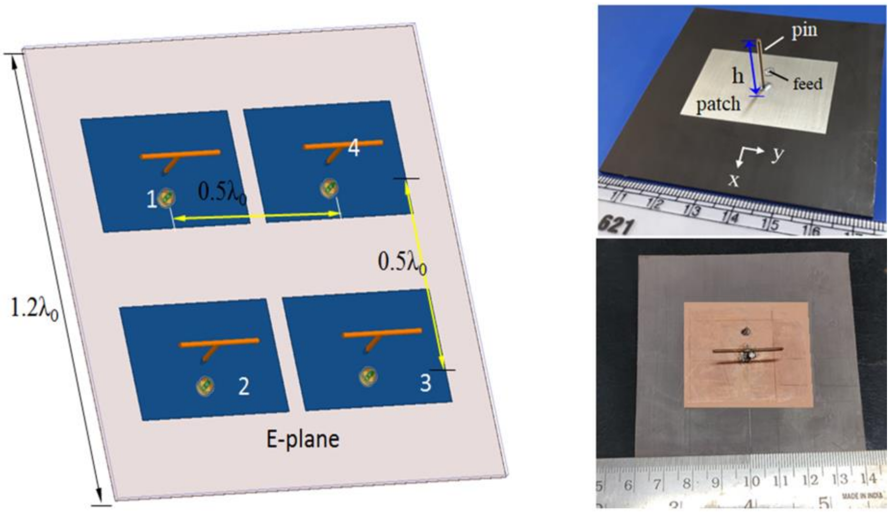


(a) (b)

Fig. 1. (a) Schematic view of a metasurface backed microstrip array, (b) The prototype ready for testing

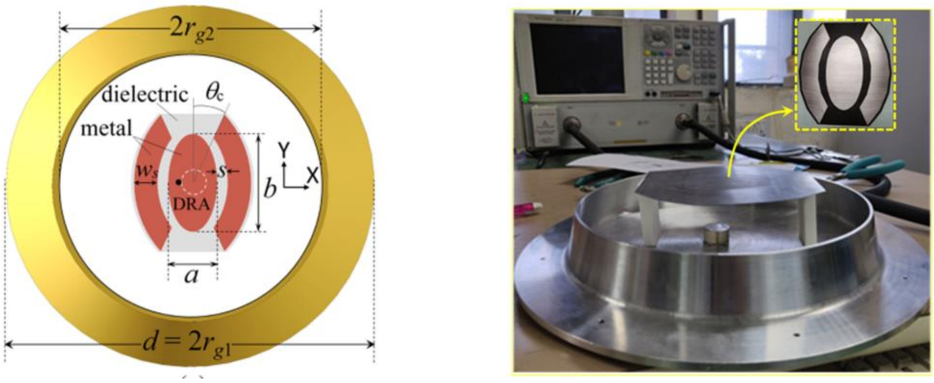
plane by an engineered metasurface (Fig.1). This surface may also help creating additional space to accommodate associated electronic circuits.

(ii) Microstrip conceived as a Metaelement: A new concept has been introduced where a microstrip element behaves like an antenna in its desired mode of resonance, but not at higher modes. This makes it immune to generating unwanted cross-polar fields. A prototype array has been tested (Fig. 2) featuring 11 dBi gain with 12 dB improvement in cross-polar isolation.



(a) (b)

Fig. 2. (a) Schematic view of the Metaelement configuration, (b) Fabricated prototype ready for testing



(a) (b)

Fig. 3. Metasurface superstrate and extended sidewall covered high gain cavity resonator antenna; (a) schematic view (b) prototype under testing

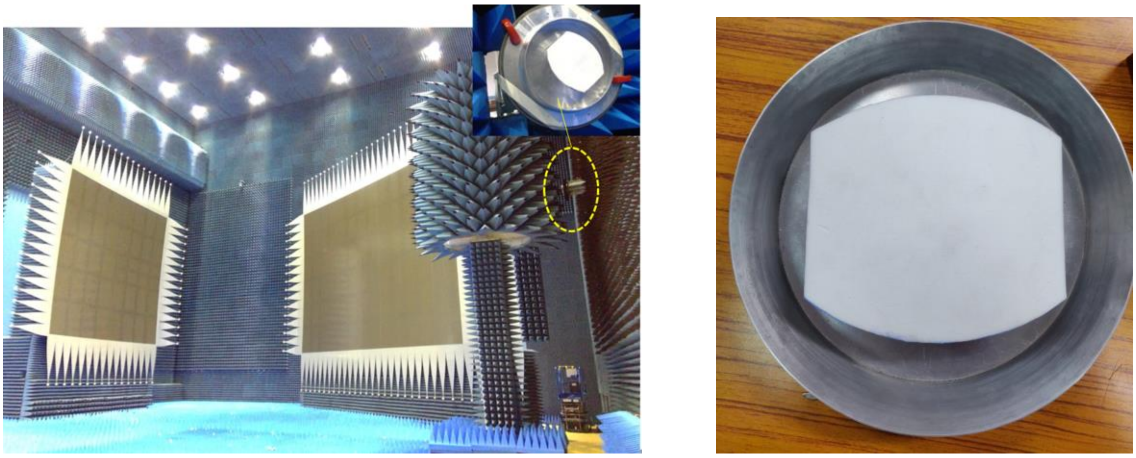
(iii) Metasurface loaded High Gain Antenna developed for 4G/5G/LTE base stations antennas:

The gain enhancement by reflection cavities has been interpreted by novel aperture-synthesis model and analysis. This work replaces the periodic reflecting surfaces by strategic geometry to achieve uniformly flat high-gain across a wide matching bandwidth. This work should be of high potential from application aspects and a few are discussed below.

(iv) Development of Low-weight, Low-cost Feed for Compact Antenna Test Facility (CATF)

(Indigenous development for a National R&D Laboratory):

The advanced feature of the antenna developed under item (iii) has encouraged us developing a Feed (Fig. 4) for characterizing C-band payload antennas in the **CATF** used in the U R Rao Satellite Centre of ISRO at Bangalore. Our newly developed Feed indeed reduces the weight of the standard commercial feed from 10kg to 1 kg and cost from $92,000 to $1000. The newly developed resonance cavity antenna serves the purpose as good as by the commercial feed without any compromise in gain, bandwidth, or cross-polar isolation.



(a) (b)

Fig. 4. (a) Metasurface induced RCA feed antenna mounted in CAT measurement chamber, (b) Close up front view

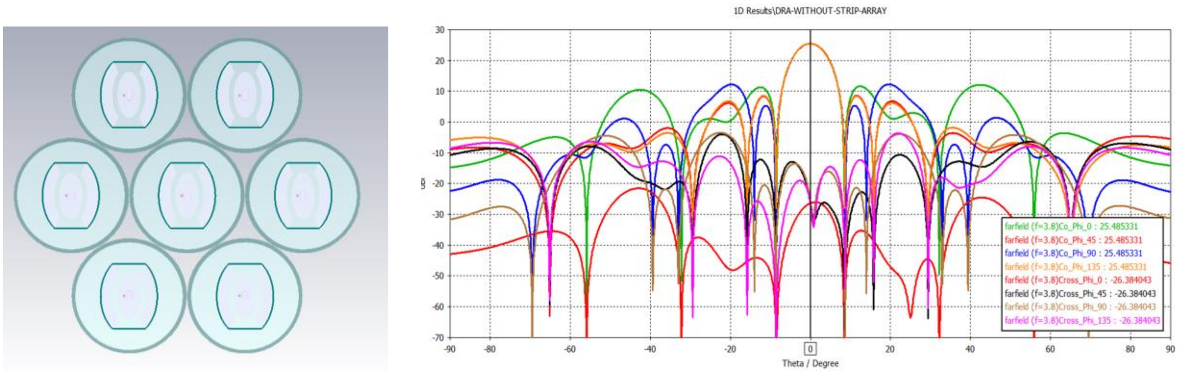


Fig. 5. Metasurface induced lightweight high gain 7 element array (a) photograph, (b) radiation patterns across different radiation planes.

(v) Developing a light-weight high-gain array for satellite payload:

The payload normally carries reflector antennas facing to ground. Our approach is to replace the reflector (which is typically of 2m diameter and weighing 25kg) by a compatible low wight array. We, therefore, have explored a new metasurface induced resonance cavity antenna in 7 element array format (Fig. 5) which closely satisfies the requirements but weighing only 2kg. Such an array needs sophisticated feed arrangements which is still under development and that may add another 2kg to the main antenna.

(vi) Industry Collaboration for the development of dual polarized dual band base station 5G Antenna

This work has been done with HCL Technologies Ltd. for 5G dual band dual polarized base station antennas. Our expertise in polarization control has been critically employed in the development and solving the polarization isolation issues. The antenna operates over the ranges (i) 880-960MHz and (ii) 1426-2000MHz. Our contribution was primarily in developing the standalone element which comprises a pair of shaped dipoles for each band. The collocated dipoles for the pair of bands have been isolated by a metasurface screen.

5. Concluding remarks: This fellowship has been utilized satisfactorily to meet our goals and objectives. We have attempted to offer real-time solutions while working on certain practical requirements in RF and Microwave domain. We sincerely thank INAE and DST for extending their support through Abdul Kalam Technology Innovation National fellowship for the three years.

APPENDIX

Book & Research Publications

Based on the works under the purview of AKF Project during 2020-2022

Book

D.Guha, C Kumar, and S. Biswas, “Defected Ground Structure (DGS) Based Antennas, Design Physics, Engineering and Application,” Dec. 2022, *IEEE Press-Wiley,* ISBN: 978-1-119-89618-0, (Dec. 2022)

Journal (13)

1. S. Rafidul, P. Mishra, **D. Guha**, and R. Bose, “Uniformly Improved Cross-polar Discrimination in a Dielectric Resonator Antenna by Conduction Current Control” ***IEEE Trans. Antennas Propag***.*(under communication).*

2. C. Kumar, C. Sarkar, and **D. Guha**, "Unnoticed Cross-polar Source in Microstrip Patch: Detection and a Practical Solution," ***IEEE Antennas and Wireless Propagation Letters*** (2022 *in press*).

3. S. Rafidul, **D. Guha**, and C. Kumar, "Sources of Cross-Polarized Radiation in Microstrip Patches: Multiparametric Identification and Insights for Advanced Engineering.," ***IEEE Antennas Propag. Mag***. (in press: doi: 10.1109/MAP.2022.3143434).

4. R. K. Chakraborty and **D. Guha**, "Dielectric Resonator Antenna-Induced Conduction Current on the Metallic Ground Plane: Interesting Observations on its Impact and Usefulness," ***IEEE Antennas Propag. Mag***. (in press: doi: 0.1109/MAP.2021.3127528).

5. D. Dutta, **D. Guha**, and C. Kumar, “Microstrip Patch with Grounded Spikes: A New Technique to Discriminate Orthogonal Mode for Reducing Cross-Polarized Radiations,” ***IEEE Trans. Antennas Propag***. vol. 70, no. 3, pp. 2295-2300, Mar. 2022.

6. M. I. Pasha, C. Kumar, and D. Guha, “Corporate-fed advanced microstrip arrays with improved cross-polar isolation: Design and engineering using DGS-integration techniques,” ***Wiley RF Microw Comput Aided Engg*.,** vol 32 (8), Aug. 2022. doi:10.1002/mmce.23357.

7. C. Sarkar, **D. Guha** and C. Kumar, "Source of cross-polar fields in a triangular patch: insight and experimental proof," ***IEEE Antennas and Wireless Propag.Lett.***, vol. 20, no. 12, pp. 2437-2441, Dec. 2021.

8. P. Gupta, D. Guha and C. Kumar, "Dual-Mode Cylindrical DRA: Simplified Design With Improved Radiation and Bandwidth," ***IEEE Antennas and Wireless Propag. Lett.***, vol. 20, no. 12, pp. 2359-2362, Dec. 2021.=

9. D. Dutta, **D. Guha,** and C. Kumar, "Mitigating Unwanted Mode in a Microstrip Patch by a Simpler Technique to Reduce Cross-Polarized Fields over the Orthogonal Plane," ***IEEE Antennas Wireless Propag. Lett.***, vol. 20, no. 5, pp. 678 - 682, May 2021.
10. K. Dutta, P. Mishra, S. Manna, A. Pal, and **D. Guha**, "Geometrical Optics Based Advanced Design of an Open Cavity Resonant Antenna," ***IEEE Antennas Wireless Propag. Lett.***, vol. 20, no. 3, pp. 322-326, Mar. 2021.

11. C. Kumar and **D. Guha,** "Higher Mode Discrimination in a Rectangular Patch: New Insight Leading to Improved Design With Consistently Low Cross-Polar Radiations," ***IEEE Transactions on Antennas and Propagation***, vol. 69, no. 2, pp. 708-714, Feb. 2021.

12. C. Kumar and **D. Guha,** "Mitigating Backside Radiation Issues of Defected Ground Structure Integrated Microstrip Patches," ***IEEE Antennas and Wireless Propagation Letters***, vol. 19, no. 12, pp. 2502-2506, Dec. 2020.

13. C. Sarkar, **D. Guha** and C. Kumar, "Hybrid Subarray Using a New Concept of Feed for Advanced Antenna and Array Designs," ***IEEE Transactions on Antennas and Propagation***, Dec. 2020.

Conference Articles: 19 (list not included)