2022

Wideband Array for BGAN Portable Terminals

Jakub Przepiorowski
Technological University Dublin

Patrick McEvoy
Technological University Dublin, patrick.mcevoy@tudublin.ie

Max Ammann
Technological University Dublin, max.ammann@tudublin.ie

See next page for additional authors

Funder: This publication has emanated from research supported in part by a grant from Science Foundation Ireland under Grant number 18/CRT/6222.

Wideband Array for BGAN Portable Terminals

Jakub Przepiorowski[1]*, Patrick McEvoy[1], Max J. Ammann[1] and X. L Bao[2]
Antenna and High Frequency Research Centre[1]
Technological University Dublin
Dublin, Ireland
School of Electrical & Electronic Engineering[2]
University College Dublin
Dublin, Ireland

*jakub.przepiorowski@ieee.org

2022 International Workshop on Antenna Technology (iWAT) | 978-1-6654-9449-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/iWAT54881.2022.9811021

***Abstract*—A circularly-polarized antenna array with sequentially rotated elements is proposed for Broadband Global Area Network L-band portable terminals. The antenna employs a 2×2 array of air-spaced annular-ring loaded circular patches. The measured results show a 3 dB axial-ratio bandwidth better than 70% (1113 - 2314 MHz) and a 10 dB S_{11} bandwidth of 56.7% (1170- 2095 MHz). The measured peak gain is 13.6 dBic.**

Keywords—Circular polarization, sequentially rotated, microstrip antenna, air gap

I. Introduction

With the increasing demand for global internet connectivity [1], services like INMARSAT's Broadband Global Area Network (BGAN) are becoming more widely used. BGAN terminals are portable devices that can be plugged into a laptop or a network in a remote location and provide access to the internet via INMARSAT's I-4 and the emerging I-6 geostationary satellites. BGAN terminals operate in the L-band with the receive band (Rx) of 1518-1559 MHz and the transmit band (Tx) of 1626.5-1675 MHz.

To improve the portability and reduce weight of these terminals, their profile and dimensions should be kept as small as possible. Microstrip antennas are well known for being lightweight and low profile and are a common choice for many mobile devices [2]. However, they come with some drawbacks such as narrow bandwidth and low gain [2]. There are many techniques for increasing the bandwidth of a microstrip antenna in the literature [3]. Those include, introduction of parasitic elements, increasing the substrate thickness, decreasing the dielectric constant of a substrate and sequentially rotating antenna elements, all of which are used in the structure of the proposed design. An air gap between the bottom feed network substrate and the top radiating patch substrate was added to reduce the effective dielectric constant of the entire antenna and increase the height of the dielectric medium increasing the bandwidth [4]. Sequentially rotated arrays have been well studied in the literature [5] and although commonly used with LP patches to create circularly-polarized (CP) arrays [5], they can also be designed using CP patches for increased axial ratio (AR) bandwidth [6].

Multiple designs of sequentially rotated arrays at L-band were proposed with conductor backed asymmetric coplanar waveguide (ACPW) network feed [7], foldable array design [8] and lightweight low-density polyethylene (LDPE) substrate design [9]. Each design focused on either increasing the gain or the AR bandwidth.

Proposed in this paper is a 2×2 CP array with sequentially rotated right-hand circularly-polarized (RHCP) circular patches operating at the L-band. The design uses an air gap as well as annular ring structure to further improve the bandwidth of the antenna. All antenna elements are microstrip which makes the fabrication and assembly quick and low cost. The feed network is fed by SMA from the back.

II. Antenna Design

A. Antenna Element Design

The use of symmetrical shapes such as a square or a circle for patch antennas allow for the use of more than one feed to generate circular polarization. A circular patch was chosen for this design with the circular polarization being generated by exciting the patch at two orthogonal points with equal amplitude and 90° phase difference. To further increase the antenna bandwidth, an annular ring was added to each patch [10]. The distance between the patch and the annular ring was optimised to be A_{gap} = 3mm and rings width to be A_{width} = 6mm. Shorting pins at optimised positions were added to the structure to eliminate any unwanted modes.

A 3D EM analysis software, CST Studio Suite, was used to optimise the dimensions of the proposed design. The geometry of the proposed design is shown in Figure 1 and the optimised design parameters are as follows: P_{rad} = 36.7 mm, A_{rad} = 45.7 mm, h = 10 mm, L_{top} = 247 mm, VT_{width} = 4 mm, $Tran_{50}$ = 3.14 mm, $Tran_{70}$ = 1.615 mm. The parameters of the sequential phase network are: R_{rad} = 15.33 mm, W_1 = 8.64 mm (25 Ω), W_2 = 14 mm (16.667 Ω), W_3 = 8.64 mm (25 Ω), W_4 = 3.14 mm (50 Ω).

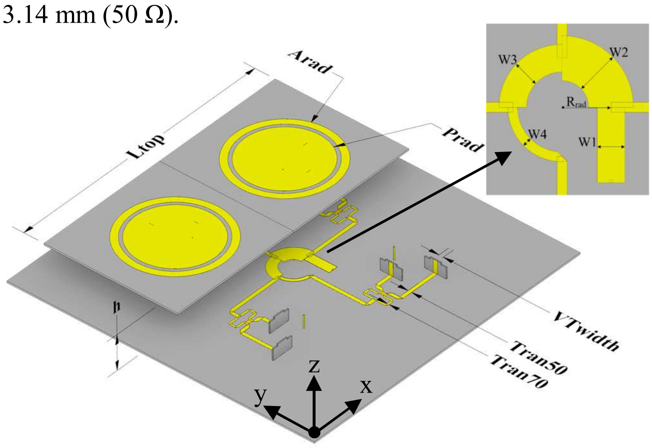

Fig. 1. Proposed 2×2 CP patch array (with 2 elements cut away) and sequential phase feed network.

This publication has emanated from research supported in part by a ant from Science Foundation Ireland under Grant number 18/CRT/6222.

B. Array Design

Vertical copper traces were used to connect the circular patches to the feed network. The vertical traces were fabricated on a FR-4 substrate of thickness 1.6mm. The substrate shape for the vertical traces was designed in such a way to increase the structural integrity of the upper layer.

The separation between the elements from center to center is 117 mm or $0.64\lambda_0$. Each element in the array is sequentially rotated and has a 90° input signal phase shift in respect to its neighboring element.

An FR-4 substrate with tanδ = 0.015 and dielectric constant, Dk, of 4.4 was used. A thickness of 1.6 mm was used for the bottom substrate and thickness of 0.8 mm for the top. The antenna dimensions are 284 mm x 284 mm x 10 mm, and the weight is 360g.

III. Experimental Results And Analysis

The return loss measurements were performed using a Rohde & Schwarz ZVA40 vector network analyser. The farfield measurements of the prototype antenna were made in an anechoic chamber. Following is a comparison between the simulated and measured results.

A. Impedance Plot

Figure 2 shows the S_{11} plots of the simulated and measured results. The simulated 10 dB S_{11} bandwidth is 52.35% (1248-2133 MHz) and the measured is 56.66% (1170-2095 MHz). Both results have return loss better than 15 dB over the required BGAN band (1518-1675 MHz).

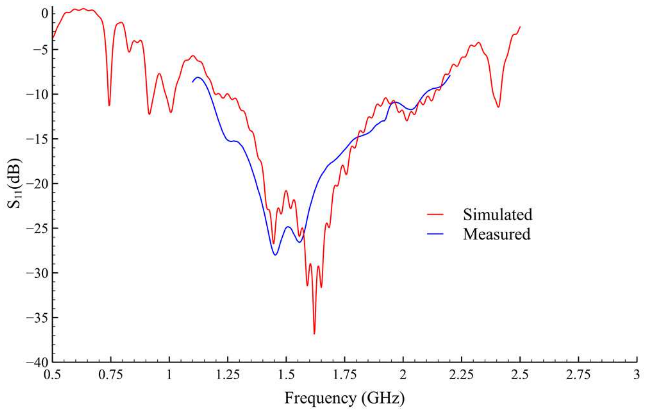

Fig. 2 Simulated and measured S11 of the proposed design.

B. Axial Ratio and Gain Plots

Figure 3 shows the simulated and measured AR and gain results of the prototype antenna. The AR can be seen to be better than 3dB between 1113 MHz to 2314 MHz yielding a bandwidth better than 70%. Over the Rx band (1518-1559 MHz) the peak measured gain was found to be 10 dBic and over the Tx band (1626.5-1675 MHz) to peak at 11.8 dBic. The peak gain across the full band was 13.6 dBic.

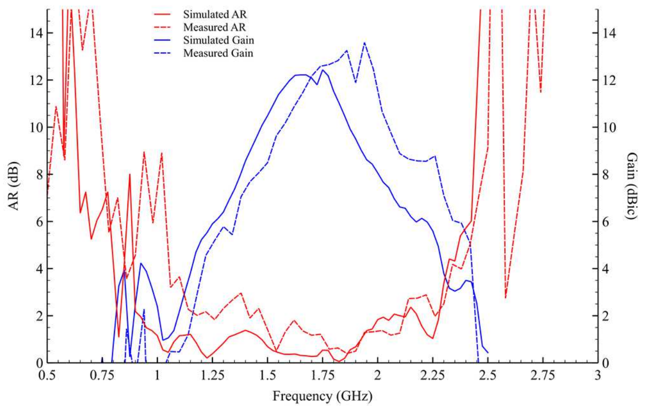

Fig. 3 Simulated and measured axial ratio and gain.

C. Radiation Patterns

The simulated RHCP, LHCP and total gain radiation patterns in planes x-z and y-z, are compared in Figure 4.

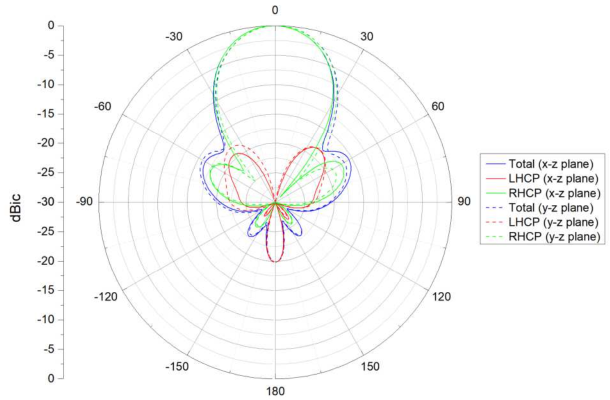

Fig. 4. Simulated radiation patterns of the x-z and y-z planes at 1650 MHz.

Figure 5 shows the measured radiation properties for the x-z plane over a range of frequencies from 1500 MHz to 1800 MHz. The side-lobe levels are greater than 14 dB over the entire band. At 1525 MHz the measured front-to-back ratio is greater than 19 dB and at 1650 MHz it is at 25 dB.

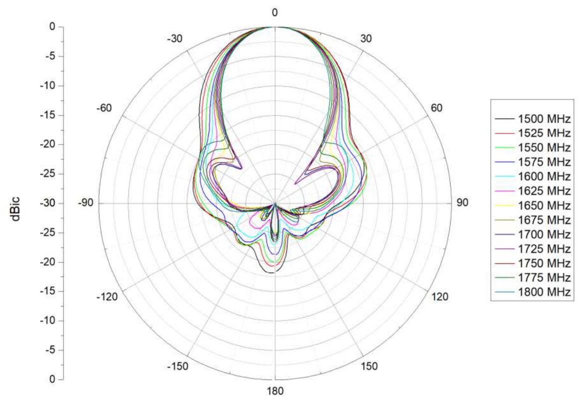

Fig. 5. Measured radiation pattern for x-z plane.

Table I. Literature Comparison

Antenna Design	AR ≤3 dB (GHz)	$S_{11} \leq$ -10 dB BW (%)	AR ≤3 dB BW (%)	Peak Gain (dBic)	Size L × W × H (mm)
Proposed	1.11 – 2.31	56.7%	70.1%	13.6	284×284×10
[7]	1.41 – 1.82	40.5%	25.6%	>11.6	240×240×19
[8]	1.52 – 1.68	>25%	<14%	13.3	300×95
[9]	1.42 – 1.7	28%	18%	>13	250×250×15
[11]	1.15 – 1.95	52%	49%	8	220×220

D. Beamwidth

Figure 6 shows the measured and simulated 3dB AR beamwidths. The measured 3 dB AR beamwidth in the x-z plane is 46.2° and in the y-z plane it is 50.79°. The measured HPBW beamwidth is 35° for both planes.

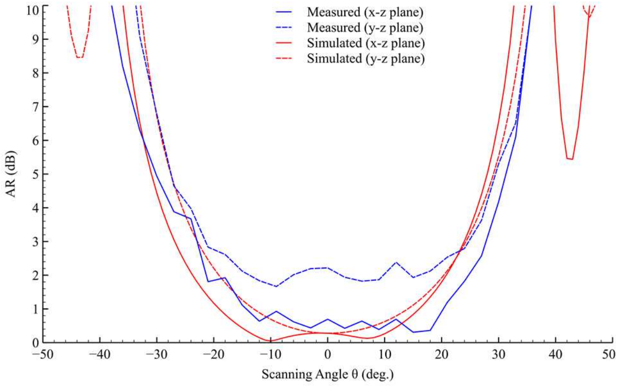

Fig. 6 Axial Ratio beamwidth.

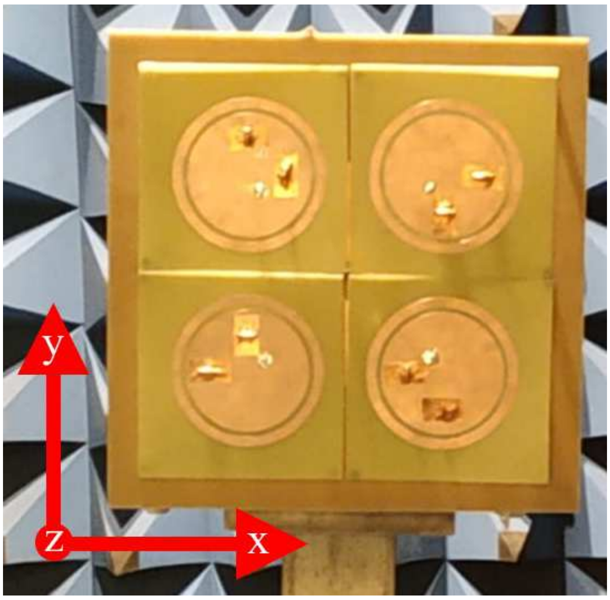

Fig. 7. The prototyped antenna.

IV. Conclusions

A 2×2 RHCP wideband array for portable BGAN terminals is presented. The proposed antenna provides a very wide operating range with a 3dB AR bandwidth greater than 70%, a peak gain of 13.6 dBic and an impedance bandwidth greater than 56%.

Acknowledgment

This publication has emanated from research supported in part by a grant from Science Foundation Ireland under Grant number 18/CRT/6222.

References

[1] P. Wang, J. Zhang, X. Zhang, Z. Yan, B. G. Evans and W. Wang, "Convergence of Satellite and Terrestrial Networks: A Comprehensive Survey," in *IEEE Access*, vol. 8, pp. 5550-5588, 2020, doi: 10.1109/ACCESS.2019.2963223.

[2] R. Garg, P. Bhartia, L. Bahl, and A. Ittipiboon, "Microstrip Antenna Design Handbook", Artech House, London, UK, 2001, pp 1-2.

[3] David M. Pozar; Daniel H. Schaubert, "Techniques for Improving Element Bandwidth," in *Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays*, IEEE, 1995, pp.155-201, doi: 10.1109/9780470545270.ch4.

[4] K. F. Lee, J. S. Dahele and K. Y. Ho, "Annular-Ring and Circular-Disc Microstrip Antennas with & without Air Gaps," *1983 13th European Microwave Conference*, 1983, pp. 389-394, doi: 10.1109/EUMA.1983.333258.

[5] S. Gao, Q. Luo, F. Zhu, *"Circularly Polarized Antennas"*,1st , Wiley-IEEE Press, 2014, pp 191-193.

[6] P. S. Hall, "Application of sequential feeding to wide bandwidth, circularly polarised microstrip patch arrays," in *IEE Proc. Microw. Antennas Propag.*, vol. 136 Pt. H, no. 5, pp. 390–398, Oct. 1989, doi: https://doi.org/10.1049/ip-h-2.1989.0070.

[7] Z. Wang, S. Fang, S. Fu and S. Jia, "An Inmarsat BGAN Terminal Patch Antenna Array With Unequal Input Impedance Elements and Conductor-Backed ACPW Series-Feed Network," in *IEEE Trans. Antennas Propag.*, vol. 60, no. 3, pp. 1642-1647, March 2012, doi: 10.1109/TAP.2011.2180325.

[8] C. Kalialakis, "A Low Cost CP Printed Antenna Array For Portable L - Band Satellite Data Terminals," in *Microwave and Optical Technology Letters*, vol. 55, no. 9, pp. 2015-2019, Sep. 2013, doi: https://doi.org/10.1002/mop.27769.

[9] S.-Q. Fu, S.-J. Fang, Z.-B. Wang, and X.-M. Li, "A wideband circular polarization antenna for portable INMARSAT BGAN terminal applications," *Microwave and Optical Technology Letters*, vol. 51, no. 10, pp. 2354–2357, Oct. 2009, doi: https://doi.org/10.1002/mop.24643.

[10] Weng Chew, "A broad-band annular-ring microstrip antenna," in *IEEE Trans. Antennas Propag.*, vol. 30, no. 5, pp. 918-922, September 1982, doi: 10.1109/TAP.1982.1142913.

[11] S. Fu, S. Fang, Z. Wang and X. Li, "Broadband Circularly Polarized Slot Antenna Array Fed by Asymmetric CPW for L-Band Applications," in *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1014-1016, 2009, doi: 10.1109/LAWP.2009.2031662.