**QUEEN'S
UNIVERSITY
BELFAST**

Low profile absorber backed extremely wideband antennas

Naeem, U., Fusco, V., Zelenchuk, D., & Cahill, R. (2020). Low profile absorber backed extremely wideband antennas. In *International Conference on Antennas and Propagation (EuCAP2020): Proceedings: Copenhagen, Denmark, Denmark Institute of Electrical and Electronics Engineers Inc.*
<https://doi.org/10.23919/EuCAP48036.2020.9136050>

Published in:

International Conference on Antennas and Propagation (EuCAP2020): Proceedings

Document Version:

Peer reviewed version

Queen's University Belfast - Research Portal:

[Link to publication record in Queen's University Belfast Research Portal](#)

Publisher rights

© 2020 IEEE.

This work is made available online in accordance with the publisher's policies. Please refer to any applicable terms of use of the publisher.

General rights

Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.

Low Profile Absorber Backed Extremely Wideband Antennas

Umair Naeem¹, Vincent Fusco², Dmitry Zelenchuk³, Robert Cahill⁴

¹ Centre for Wireless Innovation, ECIT Institute, Queen's University Belfast, Belfast, United Kingdom, u.naeem@qub.ac.uk*

² Centre for Wireless Innovation, ECIT Institute, Queen's University Belfast, Belfast, United Kingdom, v.fusco@ecit.qub.ac.uk

³ Centre for Wireless Innovation, ECIT Institute, Queen's University Belfast, Belfast, United Kingdom, d.zelenchuk@qub.ac.uk

⁴ Centre for Wireless Innovation, ECIT Institute, Queen's University Belfast, Belfast, United Kingdom, r.cahill@ecit.qub.ac.uk

Abstract—In this paper design and electromagnetic performance of a low profile and extremely wideband antenna which works from 10 to 40 GHz is presented. The differentially fed antenna benefits from suppressed back lobe radiation by exploiting the use of a resistively loaded low profile absorber. The proposed antenna uses both the reflection and absorption phenomenon in near field and exhibits two octaves of bandwidth.

Index Terms—antennas, electromagnetics, propagation, measurements.

I. INTRODUCTION

Wideband antennas are often used for imaging applications [1], but many architectures such as Vivaldi or tapered slot antennas [2], have large physical dimensions which make them difficult to integrate these with the rest of the front-end electronics. Monopole type antennas [3] generally exhibit significant back lobe radiation and the patterns are not directive which makes them unsuitable for many applications. Low profile spiral and sinuous [4] antennas can be designed to exhibit a broadband performance, however to make them directive a reflector or absorber filled cavity is required to be placed behind the radiating aperture. The former structure can significantly reduce the working frequency band, and both of these solutions results in an antenna which is bulky. Therefore in order not to compromise bandwidth, there is a need to create low profile absorbers which work in the near field and therefore can be placed in close proximity to the radiating surface.

In this paper, a solution is proposed to create a new class of unidirectional low profile wideband planar antennas. These deploy foil backed absorbers with unit cells composed of nested hexagonal loops [5]. In [6] it was shown that this type of resistively loaded FSS can be used to suppress near field backscatter and therefore may be placed in close proximity to the radiation source. The purpose of this paper is to report on the design and electromagnetic performance of a 5.5 mm thick, 35 mm diameter antenna structure which works over the frequency range of 10 – 40 GHz.

Fig. 1. Top view of a dual-polarized sinuous antenna

II. EXTREMELY WIDEBAND SINUOUS ANTENNA

An extremely wideband antenna is designed based on sinuous structure. The cells of the sinuous structure can be generated from the sinuous curve defined by (1) [4]:

$$\varphi = (-1)^p \alpha_p \sin \frac{180 \ln(r/R_p)}{\ln(\tau_p)} \quad (1)$$

Where, r and φ are the polar coordinates of the p^{th} cell, R_p is the radius and τ_p is the scale factor for the p^{th} cell. α is the sweep angle and δ is the width of the arm as shown in Fig. 1(a). The input impedance of the structure in free space, as shown in Fig. 1(b), is given by (2):

$$Z_m = \frac{60\pi}{\sin \frac{M\pi}{N}} \Omega \quad (2)$$

Where M is the mode number and N is the number of arms. A four arm sinuous antenna is simulated in free space, using CST Microwave Studio. The geometric parameters of the simulated structure are shown in Table I. It was observed that by increasing the value of R_{out} the performance of the antenna can be optimized for lower frequencies.

Fig. 2. Total efficiency of the antenna

Fig. 3. Computed 3 dB beamwidth of the antenna

TABLE I. PARAMETER VALUES FOR THE OPTIMIZED STRUCTURE

Parameter	Value	Units
R_{out} – maximum radius	10	mm
R_{in} – minimum radius	0.5	mm
α - sweep angle	40	deg
δ - width	22.5	deg
Z_{port}	180	ohm
τ - Scale factor	0.75	-

It can be observed from Fig. 2. that the total efficiency remains almost constant over the frequency range of 10 GHz - 40 GHz and the beam width fluctuates from 60-80 degrees (Fig. 3.).

III. ABSORBER BACKED WIDEBAND ANTENNA

The extremely wideband antenna as proposed in the previous section is now placed above a low profile absorber. The metal backed absorber is designed for wide frequency operation and the performance of the antenna placed close to the top surface is analyzed.

A. Metamaterial absorber

The metamaterial based absorber consists of unit cells, as shown in Fig. 4. In the CST simulator the nested hexagonal loops are modeled using a surface resistance value of 27 Ω/sq and the array is placed 3 mm below the sinuous antenna. The approximate dimensions of the hexagonal unit cell are 12 mm x 14 mm. The structure is simulated as a unit cell in a frequency domain solver and the reflectivity bandwidth of the periodic structure is optimized at normal incidence. Fig. 4 shows that 90% signal suppression

(reflectivity -10 dB) is obtained between 7.8 – 24 GHz. Fig. 5. illustrates the computed impedance of the absorber, which is close to the free space impedance (377 Ohms) over this frequency range.

Fig. 4. (Top) FSS absorber unit cell, (bottom) reflection coefficient for first Floquet mode

Fig. 5. (Red) Real and (Green) imaginary part of the impedance

B. Sinuous antenna backed by metamaterial absorber

The proposed sinuous antenna is now analyzed with the metamaterial absorber placed at the back of the antenna (Fig. 6.). The metamaterial was previously shown to suppress near-field backscatter [6]. In this application it is used to absorb the backward radiation from the antenna. The parameters of the optimized structure are detailed in Table II.

Fig. 6. Structure of the antenna backed by a metamaterial absorber

TABLE II. PARAMETER VALUES FOR THE STRUCTURE

Parameter	Value	Units
R_{out} – maximum radius	10	mm
R_{in} – minimum radius	0.5	mm
α - sweep angle	40	deg
δ - width	22.5	deg
Z_{port}	200	ohm
τ - Scale factor	0.75	-
Height above absorber	2.5	mm

Fig. 7. Return loss of the antenna with (red) and without (green) absorber

Fig. 8. Efficiency of the antenna with absorber

Although the sinuous antenna is designed to work up to 40 GHz, the operating frequency range of the metamaterial based absorber is limited to 7.8-24 GHz as shown in Fig. 5. The impact of this bandwidth limitation can be observed particularly above 24 GHz as shown in Fig. 7. and Fig. 8. It is obvious that one has to trade-off the radiation efficiency of the antenna if this technique is used. It is evident from Fig. 7. that the effect of ground plane is more pronounced for frequencies above 24 GHz, in the case of absorber backed antenna. Fig. 9. shows the radiation patterns of the structure in free space with equal front and back radiation. These results can be compared with the case when the antenna is backed by absorber, for which the radiation patterns are shown in Fig. 10. It can be observed from Fig. 10. that there are some variations in the shape of the radiation patterns of the antenna over the frequency range 10 – 40 GHz. At lower frequencies the metamaterial absorber suppresses the near field radiation, however at higher frequencies the narrower beam shape implies that the absorber behaves more like a reflector. The distance between the absorber and the radiating arms is therefore adjusted to obtain more uniform radiation patterns over the complete frequency band. It can also be observed from Fig. 10. that for radiation patterns up to 20 GHz the realized gain is lower than the computed value obtained for the radiation patterns above 30 GHz. This observation also validates the operation of the low profile absorber in near field.

Fig. 9. Co-pol patterns in (top) $\phi=0^\circ$ plane, (middle) $\phi=45^\circ$ plane and (bottom) $\phi=90^\circ$ plane, for the structure in free space

IV. CONCLUSION

A very compact unidirectional wideband sinuous antenna is designed using an innovative metamaterial which is deployed to absorb the back lobe radiation. The performance of the antenna can be further improved by increasing the bandwidth of absorber to work below and above the 7.8 - 24 GHz frequency range where 90% of the energy is absorbed.

Fig. 10. Co-pol patterns in (top) $\phi=0^\circ$ plane, (middle) $\phi=45^\circ$ plane and (bottom) $\phi=90^\circ$ plane, for the structure backed by absorber

REFERENCES

- [1] H. M. Jafari, M. J. Deen, S. Hranilovic and N. K. Nikolova, "A Study of Ultrawideband Antennas for Near-Field Imaging," in IEEE Transactions on Antennas and Propagation, vol. 55, no. 4, pp. 1184-1188, April 2007.
- [2] A. Mirbeik and N. Tavassolian, "Synthetic ultra-wideband antenna for high-resolution millimeter-wave imaging," 2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Vancouver, BC, 2015, pp. 2093-2094.
- [3] Y. Li, Q. Liu, Y. Chen, C. Li, Z. Mo and F. Li, "A compact triple wideband-notched UWB antenna," 2018 International Workshop on Antenna Technology (iWAT), Nanjing, 2018, pp. 1-4.
- [4] R. H. DuHamel, "Dual polarized sinuous antennas," U.S. Patent 4658262, April, 1987.
- [5] S. N. Zabri, R. Cahill and A. Schuchinsky, "Compact FSS absorber design using resistively loaded quadruple hexagonal loops for bandwidth enhancement," in Electronics Letters, vol. 51, no. 2, pp. 162-164, 22 1 2015.
- [6] N. McGuigan, G. Conway, R. Cahill, D. Zelenchuk and S. Zabri, "Experimental characterisation of near field backscatter from thin resistively loaded FSS absorbers," in Electronics Letters, vol. 53, no. 24, pp. 1561-1562, 23 11 2017.