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Miniaturized Wideband Circularly Polarized Hybrid Dielectric Resonator Antenna

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Defence R&D Canada – Ottawa

Technical Memorandum
DRDC Ottawa TM 2012-125
October 2012

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Abstract

This document reports on a compact circularly polarized hybrid dielectric resonator antenna (DRA) operating over the entire Global Navigation Satellite Systems (GNSS) frequency band, which includes the GPS, Galileo and GLONASS frequency bands. The proposed design is composed of a small cylinder of ceramic, a single layer substrate material and a back plate housing, and is therefore relatively easy to fabricate. The used concept consists of 4 sequentially rotated arc-shaped slots etched in the ground plane, which radiate in the lower part of the frequency band and feed the DRA in the upper part. This antenna was fabricated and characterized. It exhibits a good impedance matching from 1.22 to 1.71 GHz (33% bandwidth) thus covering the complete GNSS frequency band. The achieved gain is over 0 dBic and the axial ratio (AR) is lower than 2 dB at boresight over the 1.25-1.63 GHz frequency band. The half-power beamwidth larger than 95^o, and the AR beamwidth (AR < 3 dB) is over 130^o. Despite a slight frequency shift observed during the measurements, a good agreement was noted with the simulation. The antenna surface, including the ground plane, is 100x100 mm^2 and its height considering the back plate housing is 35 mm. To the knowledge of the authors, this is the only antenna of this size that covers the complete GNSS frequency bandwidth with such excellent overall characteristics.

Résumé

Le présent document décrit une antenne à résonateur diélectrique (ARD) hybride à polarisation circulaire fonctionnant sur toute la bande fréquentielle des systèmes de navigation par satellites (GNSS, Global Navigation Satellite Systems), notamment dans les bandes de fréquence GPS, Galileo et GLONASS. La géométrie proposée est relativement facile à fabriquer. Elle comprend un petit cylindre en céramique de forme élémentaire, une couche de substrat et un boitier métallique. Le concept utilisé repose sur 4 fentes en forme d'arc gravées dans le plan de masse du substrat et disposées en effectuant une rotation séquentielle. Ces 4 fentes rayonnent dans la partie inférieure de la bande de fréquence de l'antenne, tandis qu'elles alimentent l'ARD dans la partie supérieure de la bande de fréquence. Cet élément rayonnant a été fabriqué et caractérisé. Une bonne adaptation d'impédance a été observée entre 1.22 et 1.71 GHz, soit 33% de bande passante. Le gain obtenu est supérieur à 0 dBic et le taux d'ellipticité (TE) est inférieur à 2 dB dans l'axe sur la bande de fréquence 1.25-1.63 GHz. L'ouverture à mi-puissance est supérieure à 95^o, et l'ouverture pour un taux d’ellipticité inférieur à 3 dB est supérieure à 130^o. Malgré un faible écart en fréquence noté au cours des mesures, un bon accord avec la simulation a été observé. La surface de l'antenne est de 100x100 mm^2 en incluant le plan de masse, et sa hauteur est de 35 mm. À la connaissance des auteurs, il s’agit de la première antenne de si petite taille couvrant entièrement la bande fréquentielle GNSS avec de telles performances.

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Executive summary

Miniaturized Wideband Circularly Polarized Hybrid Dielectric Resonator Antenna:

Caillet, Mathieu; Clénet, Michel; Antar, Yahia M. M.; DRDC Ottawa TM 2012-125; Defence R&D Canada – Ottawa; October 2012.

Background: Navigation applications will be taking advantage in the near future of the multiple global navigation satellites systems (GNSS) that will be soon available. The receivers will then need antennas exhibiting an excellent axial ratio (AR) over a wide frequency band (or multiple bands) and over a wide beamwidth to overcome low horizon signal reception. The antennas commercially available do not cover the entire GNSS frequency band and their size does not always allow using them in an array configuration. A new concept was introduced by Gabriel Massie in his Master's thesis to achieve circular polarization over a wideband using a hybrid dielectric resonator antenna (DRA). This new antenna is a very good candidate for navigation applications, but it is necessary to further reduce its size. In this work, a miniaturized version of the initial antenna is investigated with the challenge of keeping the same performance, specifically the frequency bandwidth and the axial ratio of the radiation patterns.

Results: The used concept consists of 4 sequentially rotated arc-shaped slots etched in the ground plane which radiate in the lower part of the frequency band and feed the DRA in the upper part. The fabricated antenna exhibits a good impedance matching from 1.22 to 1.71 GHz (33% bandwidth) thus covering the complete GNSS frequency band. The achieved gain is over 0 dBic and the axial ratio (AR) is lower than 2 dB at boresight over the 1.25-1.63 GHz frequency band. The half-power beamwidth is larger than 95^o, and the AR beamwidth (AR < 3 dB) is larger than 130^o. Despite a slight frequency shift observed during the measurements, a good agreement was noted with the simulation. The antenna surface, including the ground plane, is 100x100 mm^2 and its height considering the back plate housing is 35 mm.

Significance: A 75% volume and 64% surface reduction of the dielectric resonator has been achieved, and the performance of the miniaturized antenna are similar to the original one. The surface of the ground plane is also 61% smaller. To the knowledge of the authors, this is the only antenna of this size that covers the complete GNSS frequency bandwidth such excellent overall characteristics.

Future plans: It would be worthwhile to measure the antenna again using a different glue to bond the dielectric resonator to the ground plane to try to reduce the air gap. If the air gap can be avoided, then it would be possible to investigate further the cause of the observed frequency shift. Also, a study must be carried out to identify techniques that could contain currents on the ground plane to a smaller area. Finally, the performance of the proposed hybrid DRA must be assessed in an array configuration.

Sommaire

Miniaturized Wideband Circularly Polarized Hybrid Dielectric Resonator Antenna:

Caillet, Mathieu; Clénet, Michel; Antar, Yahia M. M. ; DRDC Ottawa TM 2012-125 ; R & D pour la défense Canada – Ottawa; octobre 2012.

Contexte : Dans un avenir proche, les applications de navigation vont utiliser l'avantage qu'apportera la disponibilité de multiples systèmes de navigation par satellites (en anglais GNSS, Global Navigation Satellite Systems). Les récepteurs vont alors nécessiter des antennes ayant un excellent taux d'ellipticité sur une large bande de fréquences (ou sur plusieurs bandes) et sur une large ouverture afin de permettre la réception des signaux bas sur l'horizon. Les antennes disponibles sur le marché ne couvrent pas entièrement la bande GNSS, et leur taille ne permet pas toujours une utilisation en réseau. Un nouveau concept a été proposé par Gabriel Massie dans ses travaux de Maîtrise pour la conception d'une antenne à polarisation circulaire large bande basée sur un résonateur diélectrique. Cette nouvelle antenne est une solution intéressante pour les applications de navigation à venir, en revanche sa taille doit être réduite. Une version miniature de l'antenne originale est examinée ici avec comme défi de conserver les mêmes performances, en particulier la bande de fréquence et le taux d'ellipticité des diagrammes de rayonnement.

Résultats : Le concept utilisé repose sur 4 fentes en forme d'arc gravées dans le plan de masse du substrat et disposées en effectuant une rotation séquentielle. Ces 4 fentes rayonnent dans la partie inférieure de la bande de fréquence de l'antenne, tandis qu'elles alimentent le résonateur diélectrique dans la partie supérieure de la bande de fréquence. Cet élément rayonnant possède une bonne adaptation d'impédance entre 1.22 et 1.71 GHz, soit 33% de bande passante. Le gain obtenu est supérieur à 0 dBic et le taux d'ellipticité (TE) est inférieur à 2 dB dans l'axe sur la bande de fréquence 1.25-1.63 GHz. L'ouverture à mi-puissance est supérieure à 95°, et l'ouverture pour un taux d'ellipticité inférieur à 3 dB est supérieure à 130 °. Malgré un faible écart en fréquence noté au cours des mesures, un bon accord avec la simulation a été observé. La surface de l'antenne est de 100x100 mm^2 en incluant le plan de masse, et sa hauteur est de 35 mm.

Importance : Une réduction de volume de 75% et de surface de 64% du résonateur diélectrique a été obtenue tout en conservant des performances similaires à l'antenne originale. La surface du plan de masse est également 61% plus petite. À la connaissance des auteurs, il s'agit de la première antenne de si petite taille couvrant entièrement la bande fréquentielle GNSS avec de telles performances.

Perspectives : Il serait utile de mesurer à nouveau l'antenne en utilisant une colle différente pour fixer le résonateur diélectrique au plan de masse afin de réduire le gap d'air. Si cela est faisable, il serait alors possible d'examiner plus précisément la cause du décalage en fréquence observé lors des mesures. De plus, une étude devra être menée pour identifier des techniques permettant de confiner les courants sur le plan de masse. Enfin, les performances de l'antenne présentée devront être évaluées dans une configuration réseau.

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Acknowledgements

The Authors would like to acknowledge Mr David Lee, Head of the antenna measurement facility at the Communication Research Centre, for measuring the radiation patterns of the antenna prototypes.

1 Introduction

Most satellite communication and navigation systems transmit signals using Circularly Polarized (CP) waves to benefit from the advantages that CP waves offer. Circularly polarized antennas having good Axial Ratio (AR) over the operating frequency band and over a wide Half-Power BeamWidth (HPBW) are then required to establish and maintain satellite links from any location on Earth. Particularly, navigation applications will be taking advantage in a near future of the multiple global navigation satellites systems (GNSS) that will be soon available. The receivers will then need antennas exhibiting an excellent axial ratio (AR) over a wide frequency band (or multiple bands) and over a wide beamwidth to overcome low horizon signal reception. The antennas commercially available do not cover the entire GNSS frequency band and their size does not always allow using them in an array configuration.

In [1], a new concept was introduced to achieve wideband circular polarization using a Dielectric Resonator Antenna (DRA). The proposed design includes a cylindrical DRA having a dielectric permittivity of 10 fed by four slots whose radiating bands combine to enhance the antenna bandwidth. This type of DRA is called a hybrid DRA (H-DRA). It covers the GNSS frequency band (1.16-1.62 GHz) and has very good performance. The antenna dimensions are 63.5 mm in diameter and 22 mm in height for the resonator, and 160 mm by 160 mm for the ground plane. The size of the antenna prevents its use in an array configuration, which is required in some applications. This report investigates the miniaturization of the initial antenna with the challenge of keeping the same performance, especially the frequency bandwidth and the axial ratio of the radiation patterns.

The geometry of the resulting optimized antenna and its simulated performance are presented in Section 2. Section 3 highlights the fabrication and measurement results. Finally, Section 4 provides conclusions and perspectives.

2 Antenna geometry and design

This section focuses on the antenna geometry and design. A parametric study has been carried out to identify the critical parameters of this antenna. The performances of the antenna have been optimized using the commercially available HFSS software [2]. The considered criteria for the optimization were the impedance matching, the gain and the axial ratio beamwidth.

The geometry of the optimized antenna and its simulated characteristics are presented first. The parametric study is reported in Section 2.3.

2.1 Antenna geometry

Figure 1 shows the geometrical parameters of the antenna. To miniaturize the antenna size, a permittivity of 30 has been used for the dielectric resonator (Emerson & Cuming Hik500, [3]). Four arc-shaped slots are used to feed a cylindrical DRA. The arc shape allows confining the slots below the dielectric resonator and thus maintains a uniform loading of the slots. The four microstrip lines are printed on a substrate material of permittivity 10.2 (Taconic CER-10, [4]). A back plate housing is used to enclose the feeding circuit and reduce back radiation. There is an electrical contact between the back plate and the ground plane.

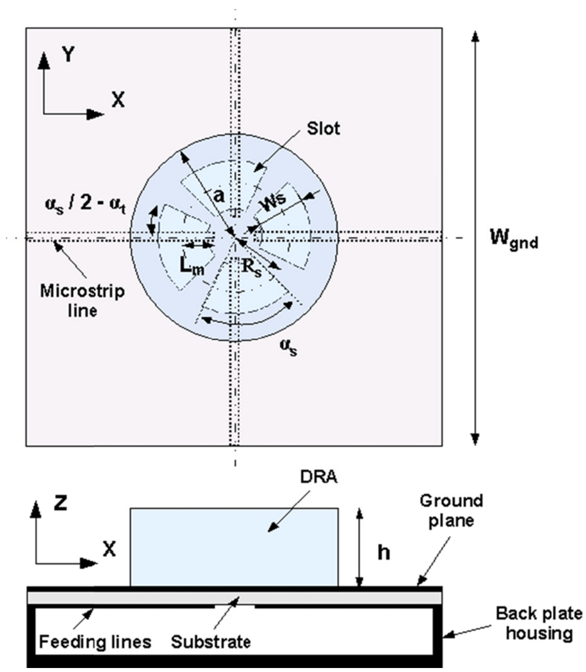


Figure 1: Compact hybrid DRA geometry.

The simulations were carried out without modeling the feeding system necessary to obtain the circular polarization. The reflection coefficient of one port is presented when the three other ports are terminated to 50 Ohms. The radiation patterns were obtained by feeding each port with a 90^o phase difference to obtain radiation pattern in circular polarization.

2.2 Optimal design

The antenna parameters R_s, L_m, α_t, h, and W_s have been optimized sequentially to achieve circular polarization over the 1.16-1.62 GHz frequency bandwidth. The optimized dimensions are given in Table 1.

Table 1: Dimensions of the optimized compact hybrid DRA (in mm, except α_s and α_t in deg.).

a	19.05
h	15.11
R_s	12.5
W_s	11.8
α_s	89
W_l	0.72
L_m	8
α_t	10
W_{gnd}	100

The simulated characteristics are presented in Figure 2 to Figure 4. The results show good matching from 1.15 to 1.65 GHz, for an impedance bandwidth of 35.7%. The gain at boresight is above 0 dBic over the entire frequency band. The half-power beamwidth of the antenna is 100 deg. over the GNSS frequency band. The axial ratio at boresight is under 0.15 dB over the entire frequency band, and the beamwidth for an AR lower than 3 dB) is 200 deg. at 1.15 GHz, 170 deg. at 1.4 GHz and 120 deg. at 1.6 GHz.

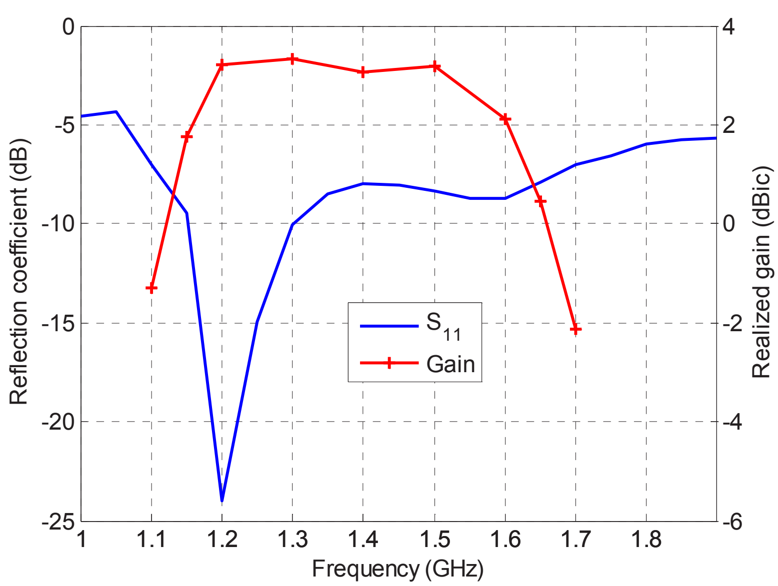


Figure 2: Simulated reflection coefficient and maximum gain of the miniature H-DRA.

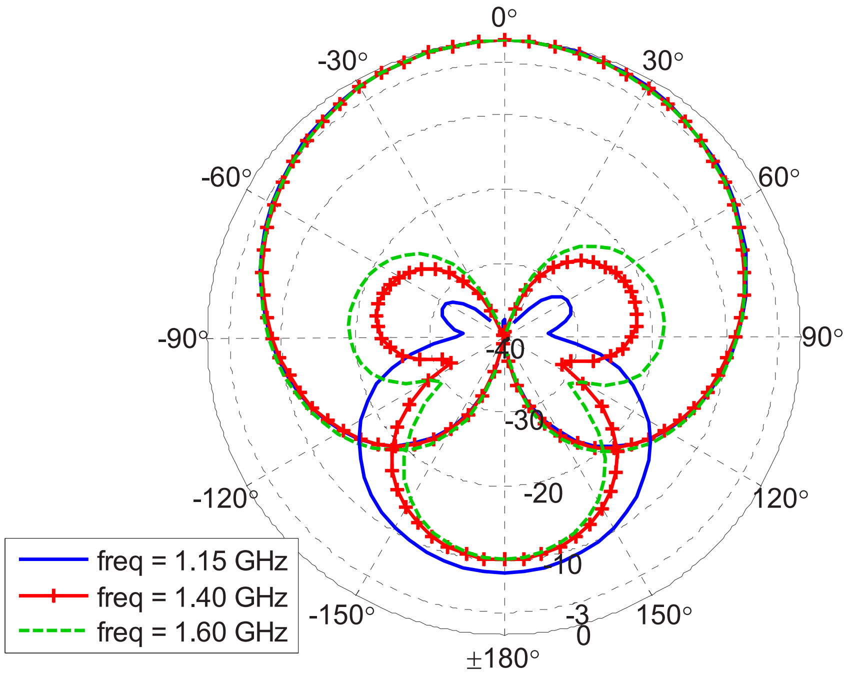


Figure 3: Simulated radiation patterns of the miniature H-DRA.

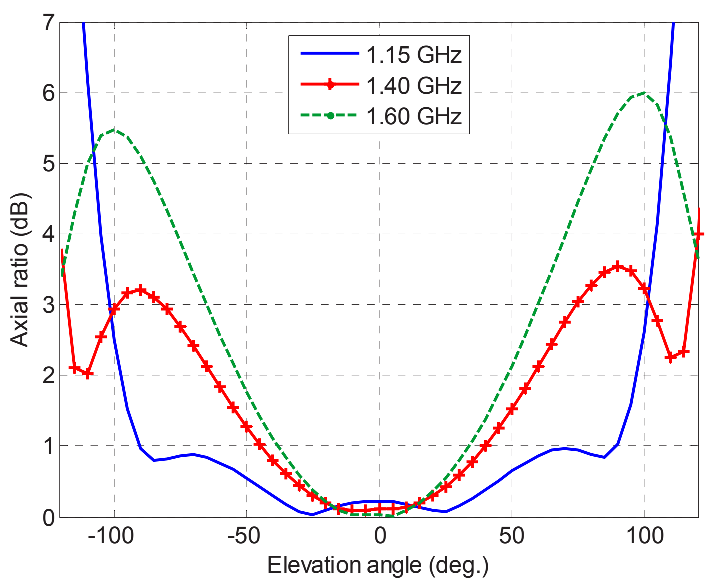


Figure 4: Simulated axial ratio in the boresight direction.

2.3 Parametric study

A parametric study has been carried out to identify the critical parameters of this antenna. The simulated results are analysed in this section.

R_s is the radius of the arc-shaped slots. It is a critical parameter because it affects both the slots' length and location. R_s should have the proper value to allow coupling to the dielectric resonator and radiation from the slots in the lowest portion of the antenna operating frequency band. Figure 5 shows the reflection coefficient and absolute gain as a function of R_s. The length R_s mostly affects the performance at low frequencies, which corresponds to the band where the slots are radiating.

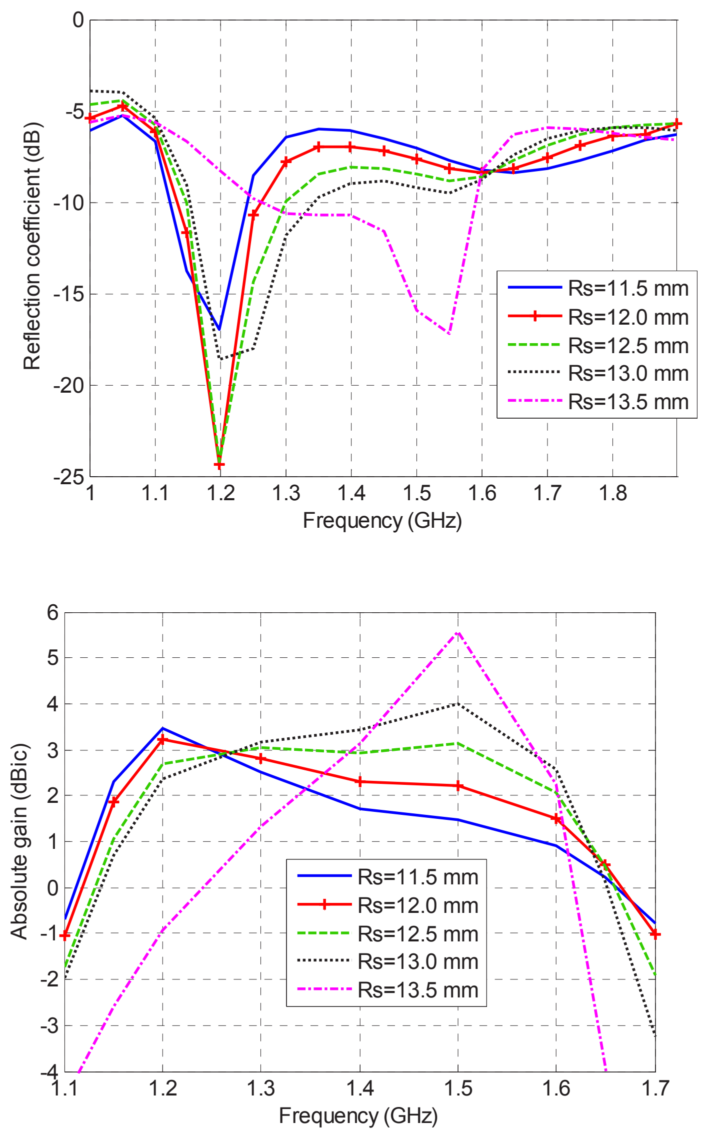


Figure 5: Reflection coefficient (top) and absolute gain (bottom) for different values of Rs.

Another important parameter is L_m, the length of the serial stubs of the microstrip lines. The stubs help to match the input ports to the slots. In Figure 6, the reflection coefficient and absolute gain are presented for different values of L_m. One can see a frequency shift in the upper part of the band, which are the frequencies where the dielectric resonator operates.

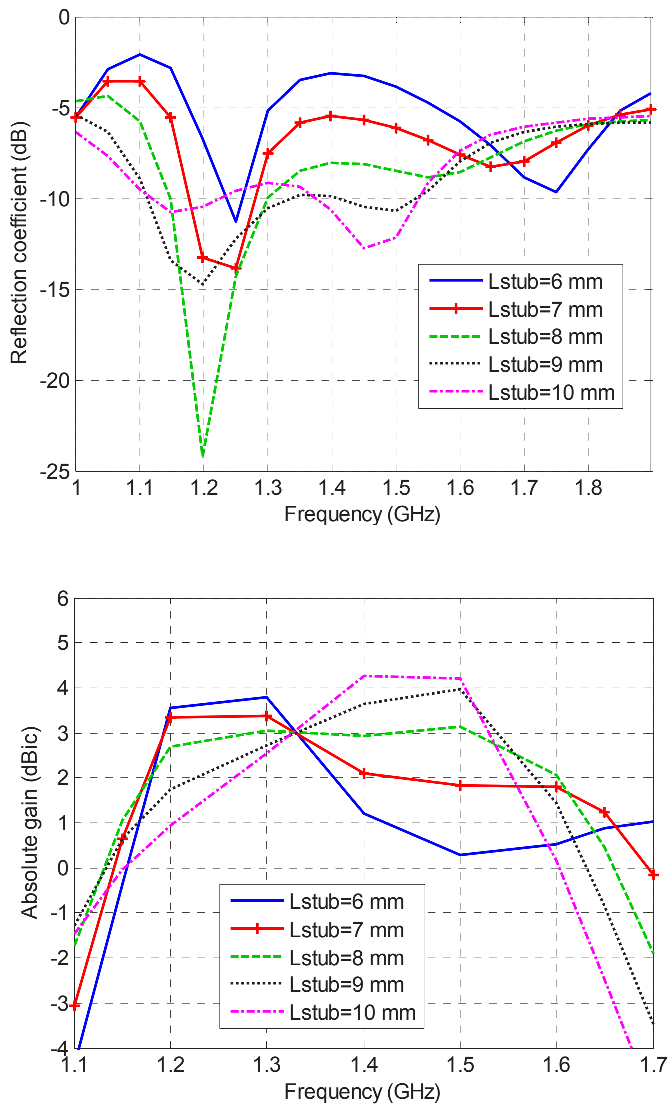
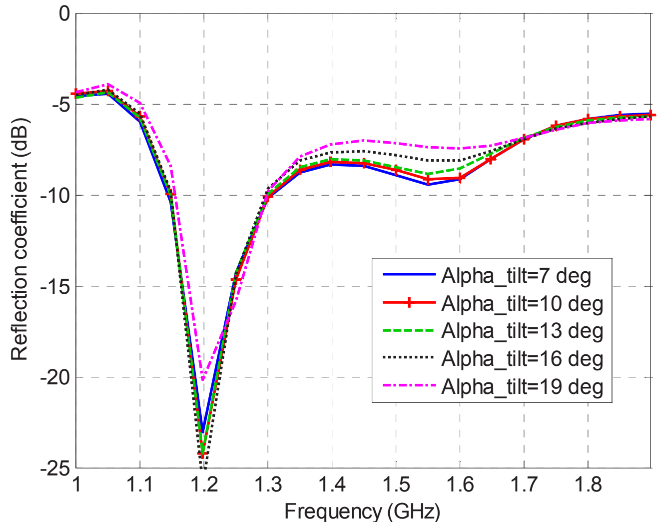


Figure 6: Reflection coefficient (top) and absolute gain (bottom) for different values of Lm.

α_t is also a parameter of interest for the hybrid DRA. Indeed, α_t controls the antenna matching as well, as seen in Figure 7. When α_t is varying by 12°, the reflection coefficient fluctuates by 2 to 4 dB and the absolute gain by less than 1 dBic.



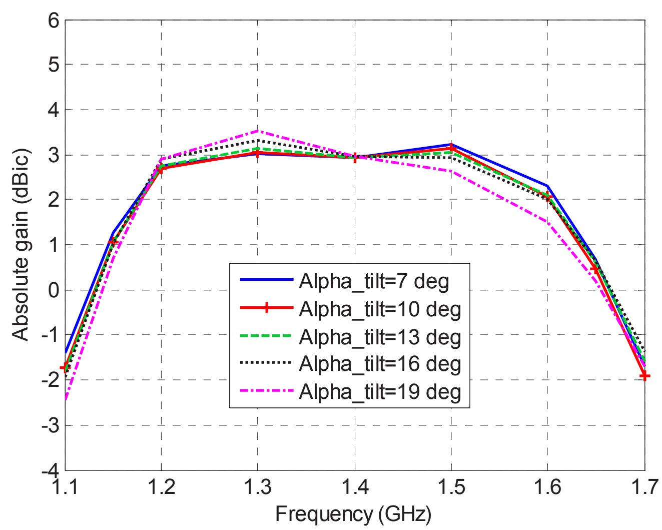
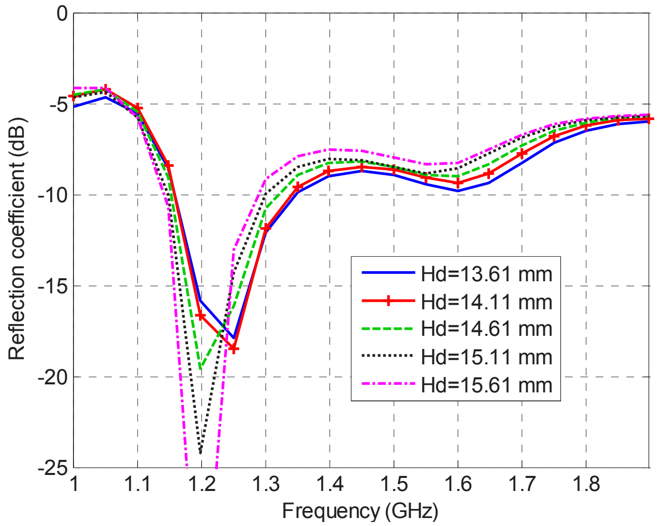


Figure 7: Reflection coefficient (top) and absolute gain (bottom) for different values of α_t.

Finally, h (height of the dielectric resonator) and W_s (width of the arc slot) are minor parameters. A variation of h causes a slight frequency shift, and W_s slightly affects the reflection coefficient (up to 4 or 5 dB) and the absolute gain (less than 1 dBic). The results are presented in



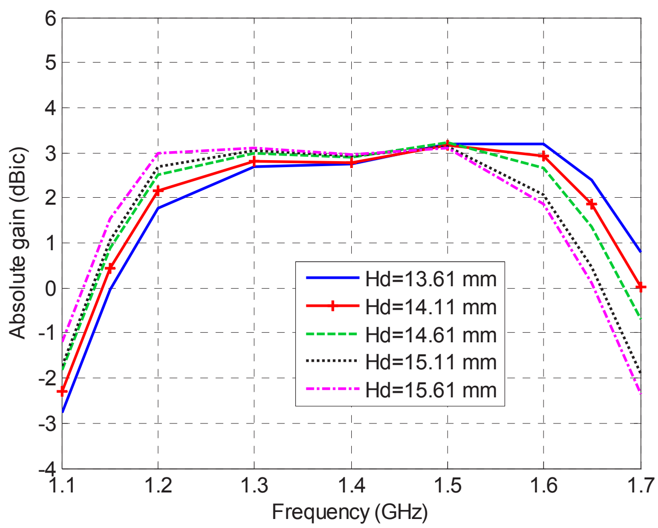
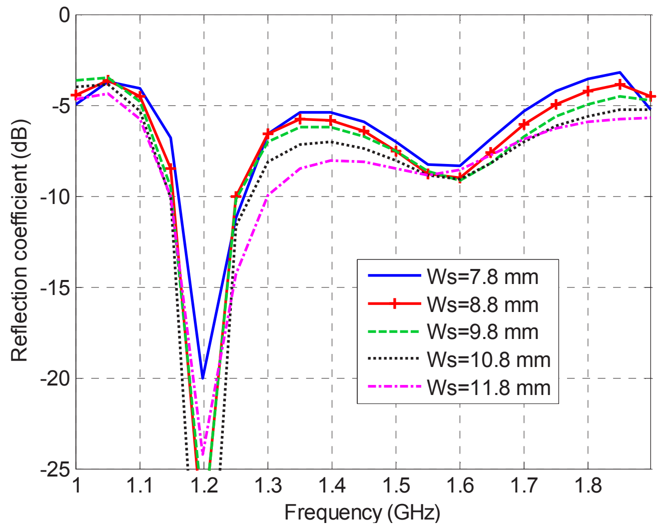


Figure 8 and



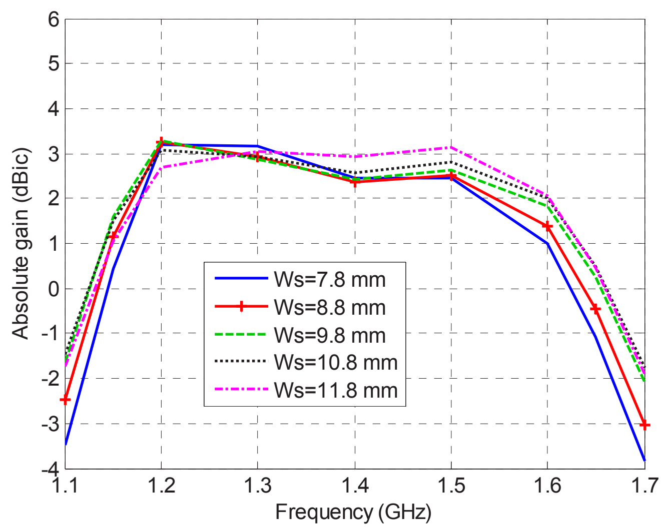
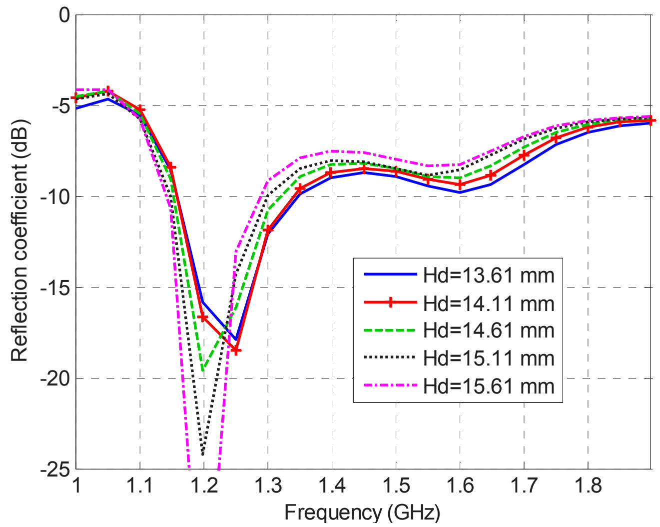


Figure 9, respectively.



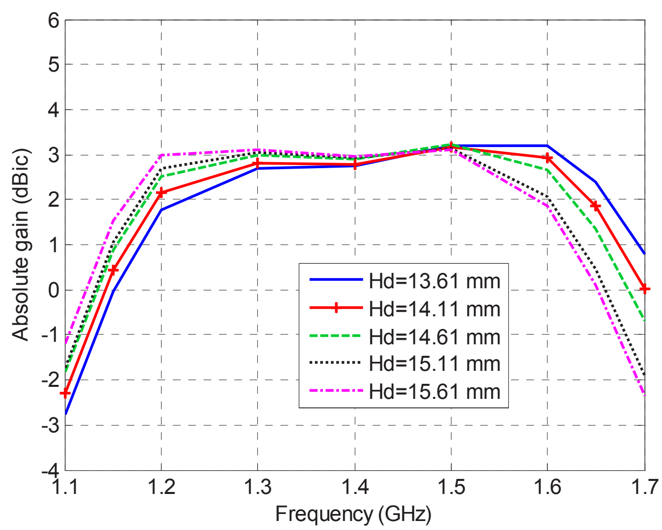


Figure 8: Reflection coefficient (top) and absolute gain (bottom) for different values of h.

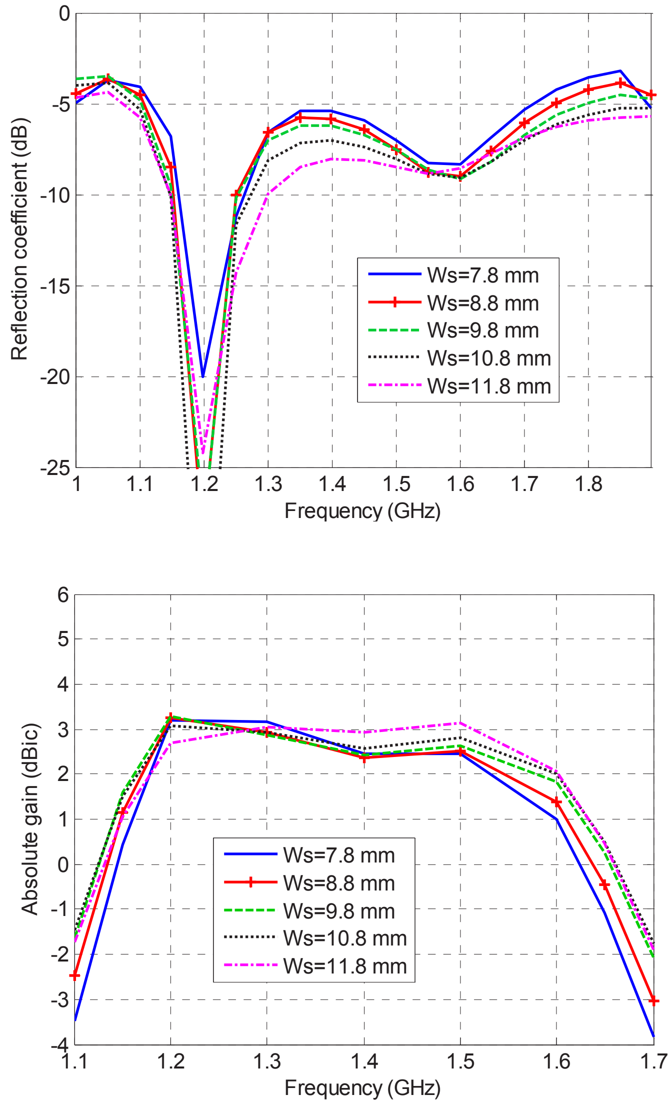


Figure 9: Reflection coefficient (top) and absolute gain (bottom) for different values of Ws.

For all the mentioned parameters, the radiation patterns and axial ratio are fairly constant for the different simulated values.

3 Fabrication and measurements

The optimised antenna has been fabricated and measured. The achieved performances are presented here.

3.1 Antenna fabrication and assembly procedure

The cylindrical Dielectric Resonator (DR) was fabricated using a 1.5” rod of dielectric material of permittivity 30 [3]. The printed circuit board (PCB) used to support the ground plane, an arc-shape slot and feeding system was chemically etched. The DR was glued on the circuit board using sealant silicon. Then, an aluminum frame was screwed to the circuit board perimeter to provide mechanical support to the antenna and hold an SMA connector. Finally, a back plate housing was mounted on the frame to reduce back radiation. The spacing between the substrate and the back plate is 13 mm. The assembled antenna is shown on Figure 10.

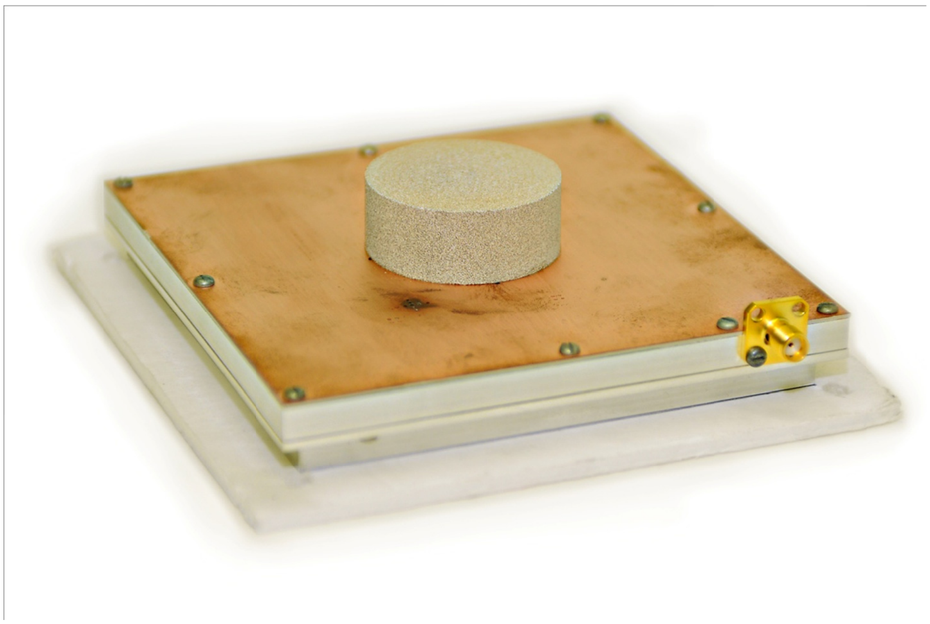
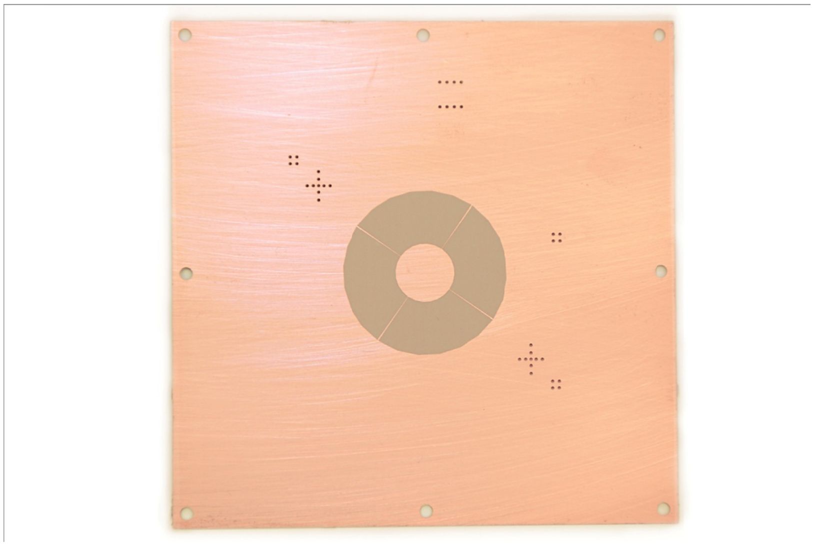


Figure 10: Antenna prototype.

For testing purposes two different PCB were etched. On the first one the arc-shape slots were etched on the top layer (Figure 11a) and the back layer supports four microstrip lines that feed independently the four slots. This design was fabricated to verify functionality of the hybrid dielectric resonator antenna in comparing directly simulated and measured results. On the second PCB a feeding circuit was etched on the bottom layer, as shown in Figure 11b. This feeding circuit, designed in a previous project [5], [6], combines the output of the four slots with a 90^{o} phase difference to generate the required right-hand circular polarization.

a)



b)

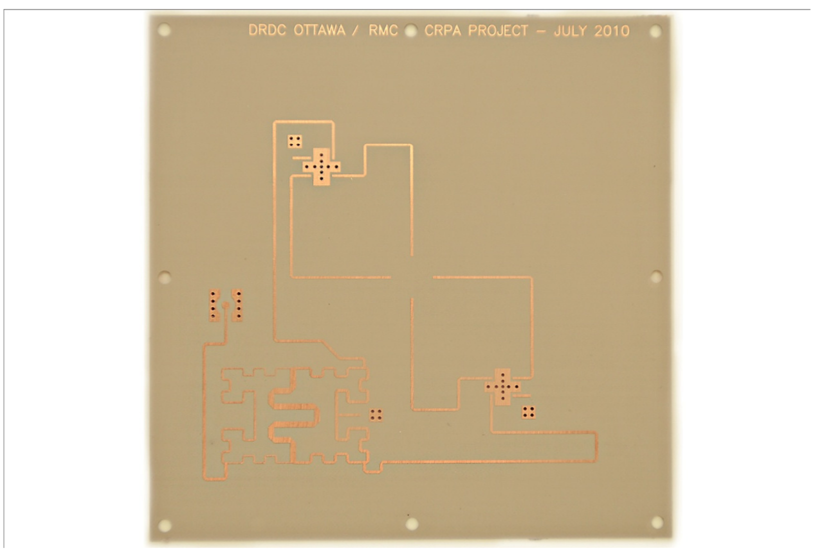


Figure 11: (a) Top and (b) bottom layers of the H-DRA PCB.

3.2 Antenna measurement

The measured antenna characteristics are presented in Figure 12 to Figure 16. One can see a frequency shift between simulation and measurement of the reflection coefficient and gain responses. The frequency shift is investigated in the next section.

Performances are still acceptable. One can however notice a reflection coefficient of -7 dB, -13 dB and -8 dB at 1.175, 1225 and 1.575 GHz, respectively. The gain at these frequencies (that correspond to L5, L2 and L1 GPS bands) is -3.5, -1.0 and 1.4 dBic, respectively.

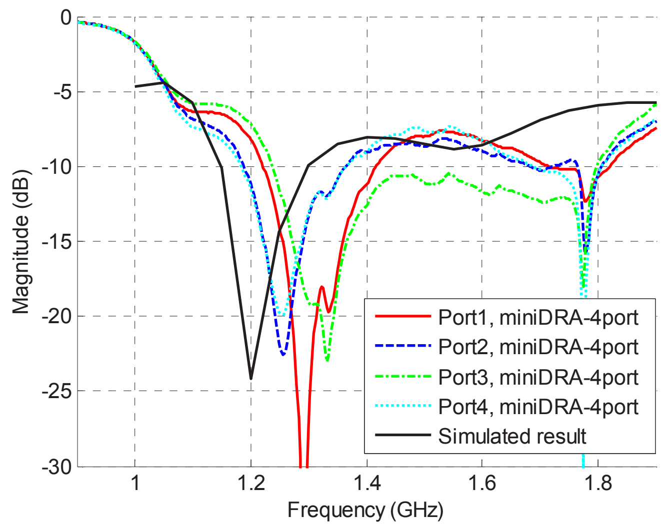


Figure 12: Measured reflection coefficients of the 4-port H-DRA.

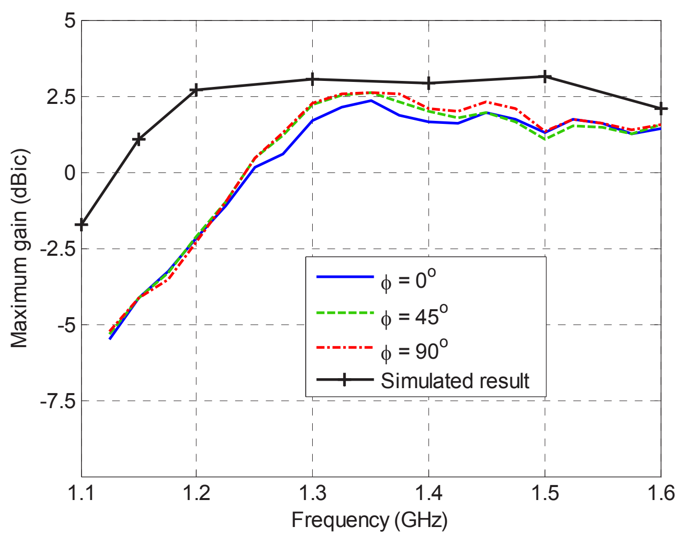
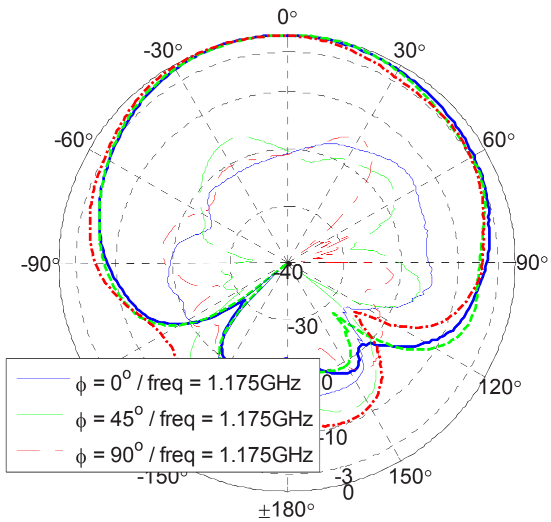


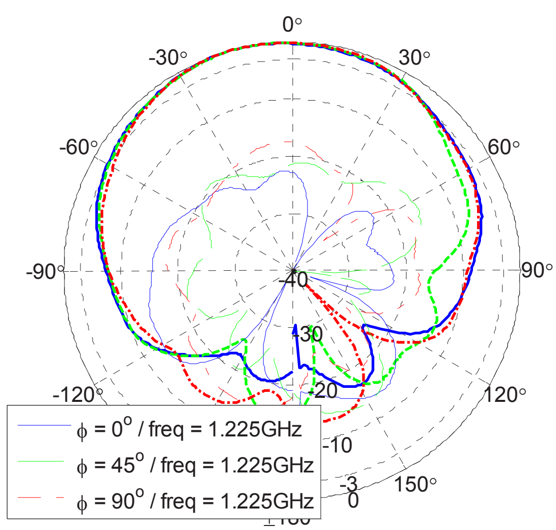
Figure 13: Measured H-DRA maximum gain in the three main planes.

The radiation patterns are presented in three planes for three frequencies, corresponding to L5, L2 and L1 GPS bands (Figure 14). Similar characteristics are observed: a wide half-power beamwitdth (HPBW) and low cross-polarization over a wide beamwidth. The HPBW is 120° at 1.175 GHz, 105° at 1.375 GHz and 95° at 1.575 GHz.

a)


0°
30°
60°
90°
120°
150°
±180°
-150°
-90°
-60°
-30°
-40
-30
-10
-3
0
φ = 0° / freq = 1.175GHz
φ = 45° / freq = 1.175GHz
φ = 90° / freq = 1.175GHz

b)


0°
30°
60°
90°
120°
150°
-120°
-90°
-60°
-30°
-40
-30
-20
-10
-3
0
φ = 0° / freq = 1.225GHz
φ = 45° / freq = 1.225GHz
φ = 90° / freq = 1.225GHz

c)

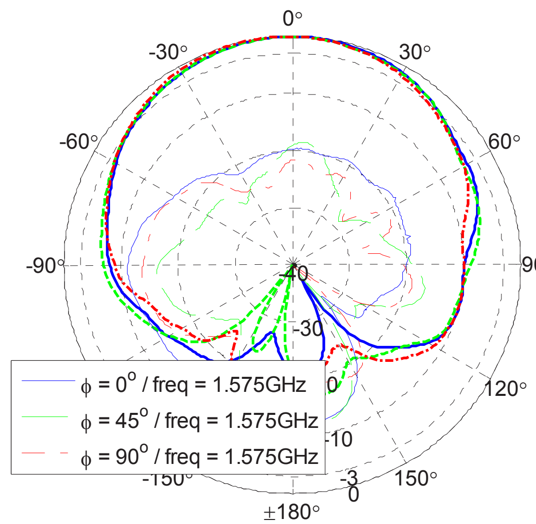


Figure 14: Measured H-DRA radiation patterns in 3 cuts for three frequencies.

The axial ratio in the boresight direction has been computed from measurement in the three cuts. Discrepancies can be observed between the different cuts. They are mainly attributed to the fact that the antenna was not exactly positioned at the centre of rotation of the positioner and to the anechoic chamber errors. The results are however consistent and shows very good circular polarization performance. The AR is about 0.8 dB at 1.175 GHz, and 0.9 dB at 1.225 GHz and 1.575 GHz.

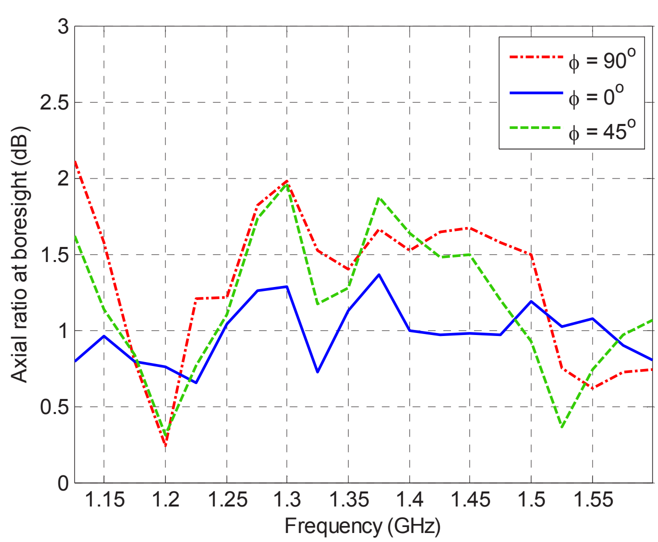
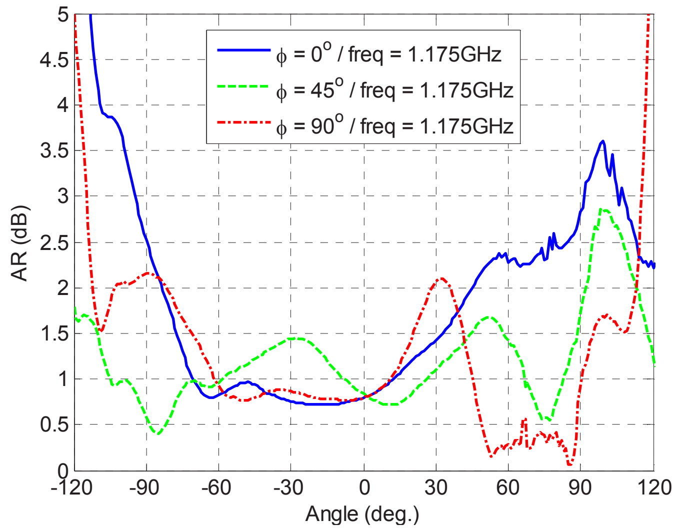


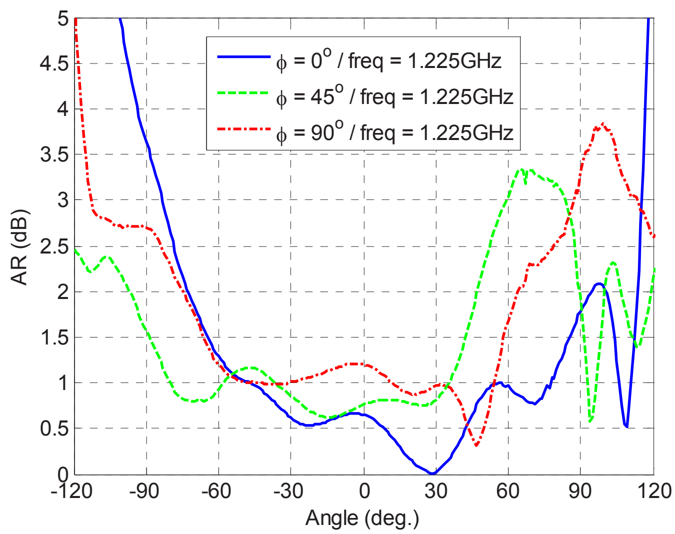
Figure 15: Measured H-DRA axial ratio at boresight.

The axial ratio response versus elevation angle has been computed from measurement in the 3 main cuts for three frequencies. Discrepancies can be observed between the different cuts. They are attributed to the antenna placement and the anechoic chamber errors. The results are however consistent and shows very good circular polarization performance. The AR beamwidth is 185° at 1.175 GHz, 130° at 1.375 GHz, and 150° at 1.575 GHz.

a)



b)



c)

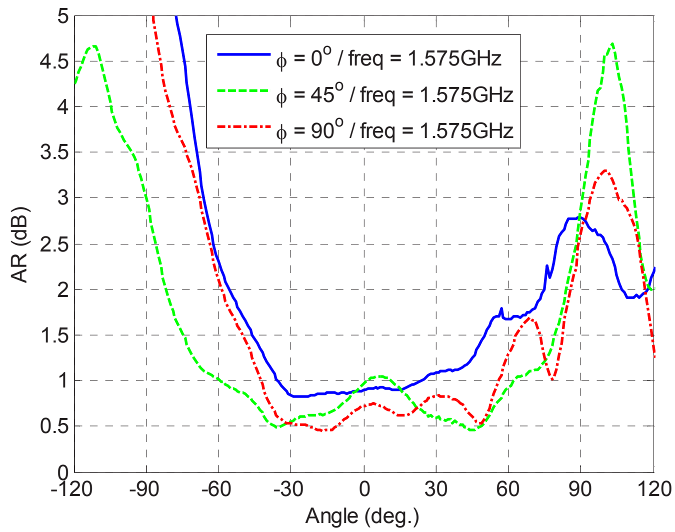


Figure 16: Measured H-DRA axial ratio versus elevation angle in three cuts for three frequencies - a) 1.175 GHz, b) 1.225 GHz, and c) 1.757GHz

Table 2 summarized the measured characteristics of the hybrid dielectric resonator antenna. Note that the reported reflection coefficient corresponds to the measurement of the 4-port prototype, and the radiation characteristics were extracted from the radiation patterns and gain measurement of the complete H-DRA, which includes the feeding circuit necessary to achieve the circular polarization.

Table 2: Summary of the measured characteristics of the H-DRA prototype

	1.175 GHz (~L5)	1.225 GHz (~L2)	1.575 GHz (~L1)
Reflection Coefficient (dB)	-7.0	-13.0	-8.0
VSWR	2.6	1.6	1.4
Gain (dBic)	-3.5	-1.0	1.4
HPBW (deg.)	120	105	95
Boresight AR (dB)	0.8	0.9	0.9
Beam width for AR < 3 (deg.)	185	130	150

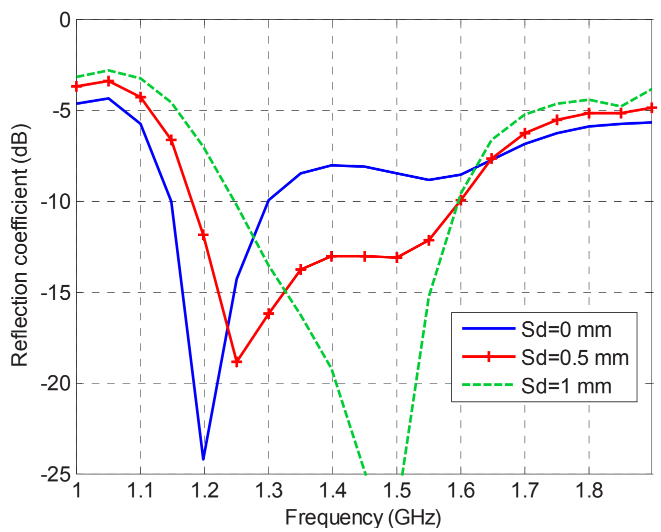
3.3 Assembly error effects

To understand the frequency shift in the antenna performance, three areas have been identified for potential errors after assembly: the location of the DR, the air gap between the dielectric resonator and the ground plane, and the DR permittivity. The presence of an air gap relates to the thickness of the material used to bound the dielectric resonator to the ground plane. The effects of errors on those parameters were investigated through simulation and results are reported in this section.

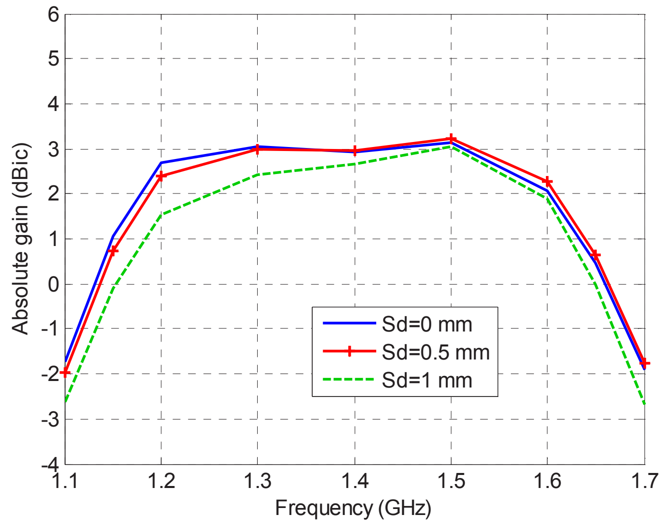
3.3.1 Dielectric resonator location

An error S_d is introduced on the DR position along both X and Y axes (see Figure 1, page 2). As shown in Figure 17, this error greatly affects the reflection coefficient and the axial ratio performance. The gain remains however fairly stable.

a)



b)



c)

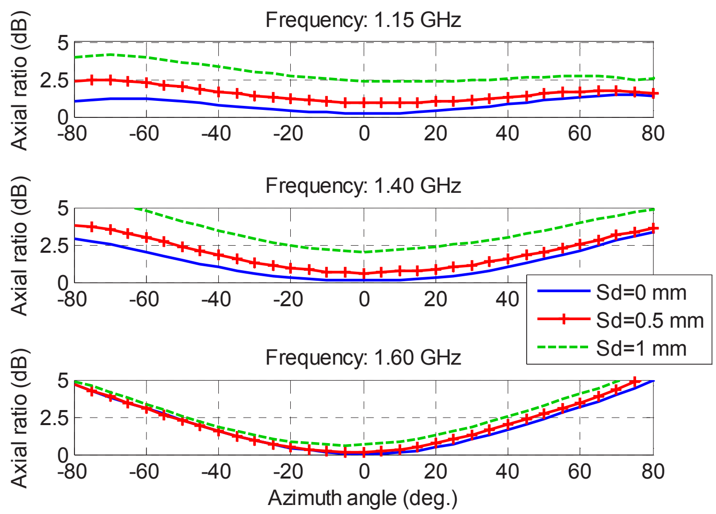
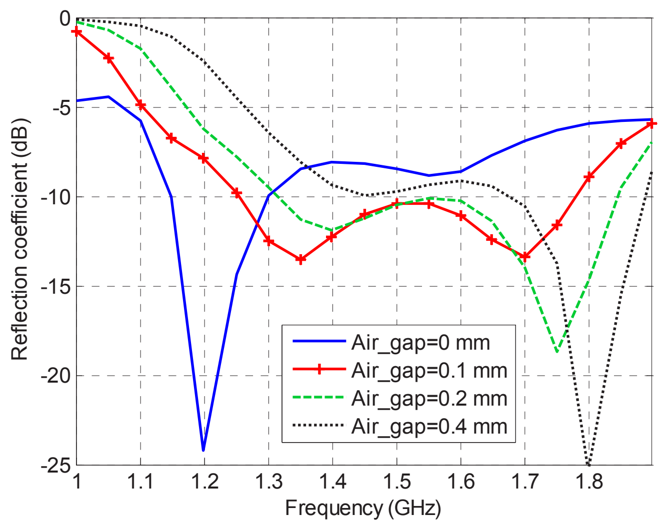


Figure 17: Hybrid DRA (a) reflection coefficient, (b) maximum absolute gain, and (c) axial ratio versus elevation for various planes as a function of the DR location.

3.3.2 Air gap between the dielectric resonator and the ground plane

The presence of an air gap between the DR and the ground plane tends to shift the resonance frequency upward and reduce the bandwidth [7]. Those phenomena can be observed in Figure 18. There is a gain increase in the upper part of the bandwidth for high air gaps. The performance degrades quickly because of the important difference in the permittivity of vacuum and the DR ($\varepsilon_r = 30$).

a)



b)

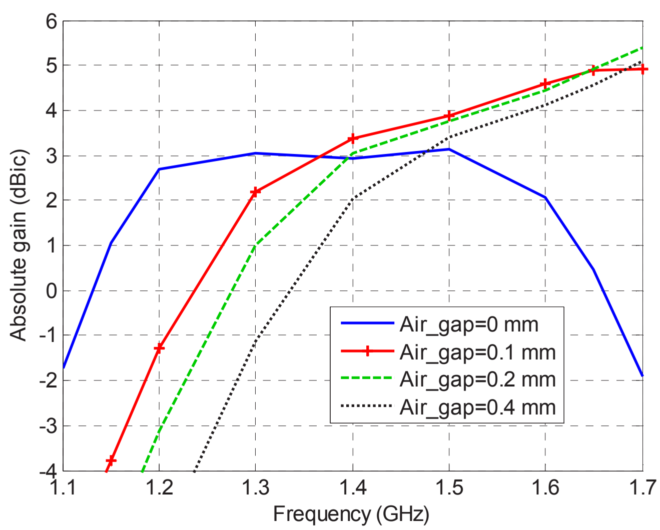
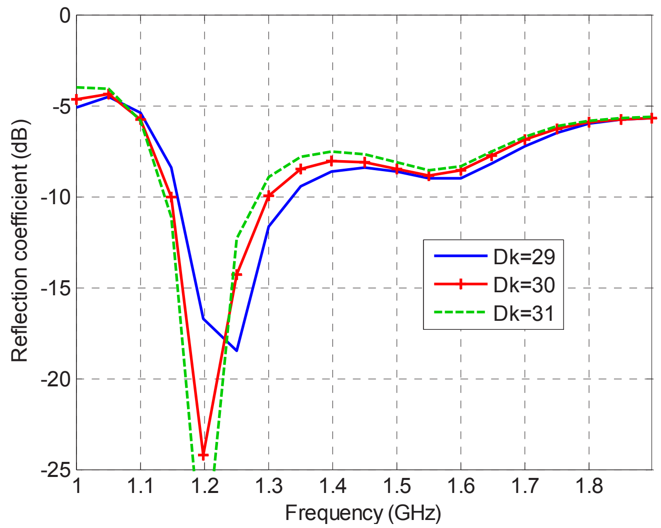


Figure 18: Hybrid DRA (a) reflection coefficient and (b) maximum absolute gain as a function of the air gap between the DR and the ground plane.

3.3.3 Dielectric resonator permittivity

As seen in Figure 19, a small variation of the permittivity of the DR has a minor impact on the antenna performance.

a)



b)

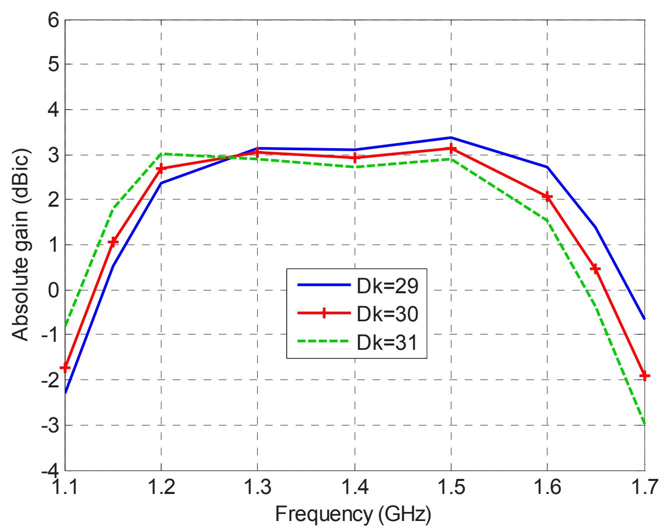


Figure 19: Hybrid DRA (a) reflection coefficient and (b) maximum absolute gain as a function of the DR permittivity.

3.3.4 Discussion

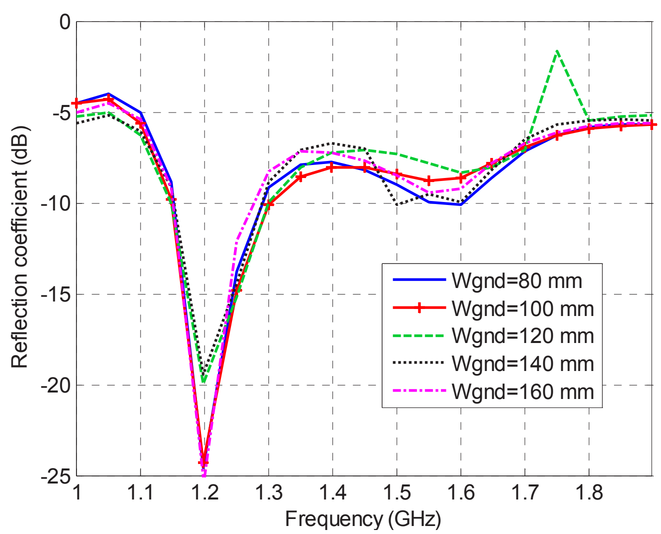
Comparing the simulation results to the measured ones, it is reasonable to believe that an air gap of about 0.1 mm causes the observed frequency shift during the measurements. The air gap is attributed to the use of the sealant silicon to glue the DR. Fabrication tolerances may be part of the observed phenomena as well, which means that the air gap height could be slightly smaller.

3.4 Ground plane size

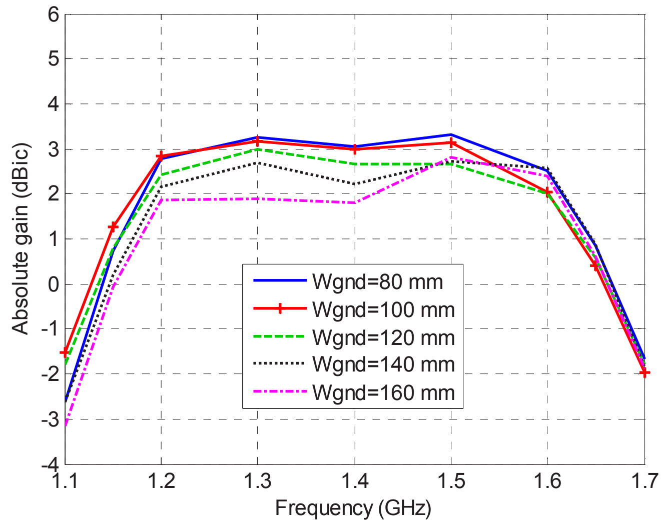
When miniaturizing antennas, the influence of the ground plane size on the performance is critical [7]. Using simulation, the effects of the ground plane size on the antenna performance are analysed. In addition, the current distribution on the ground plane is investigated.

In Figure 20, the reflection coefficient, maximum absolute gain, and axial ratio are presented for various ground plane sizes. The gain and axial ratio are mostly affected. Particularly, the larger the ground plane, the smaller the AR beamwidth.

a)



b)



c)

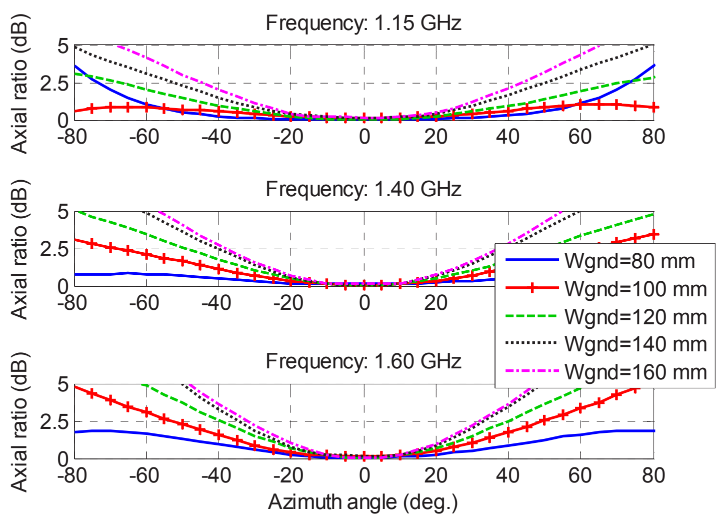
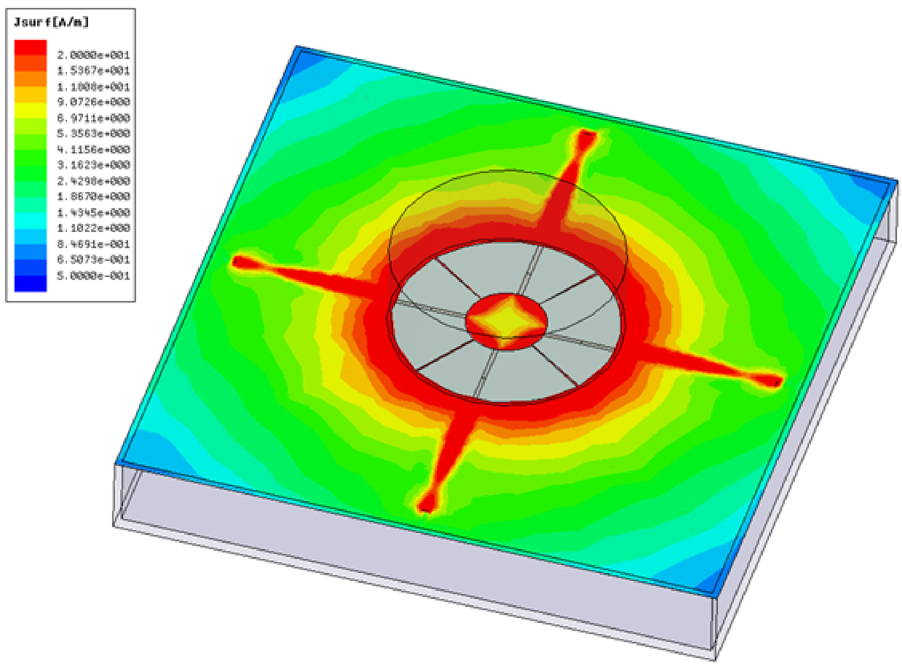


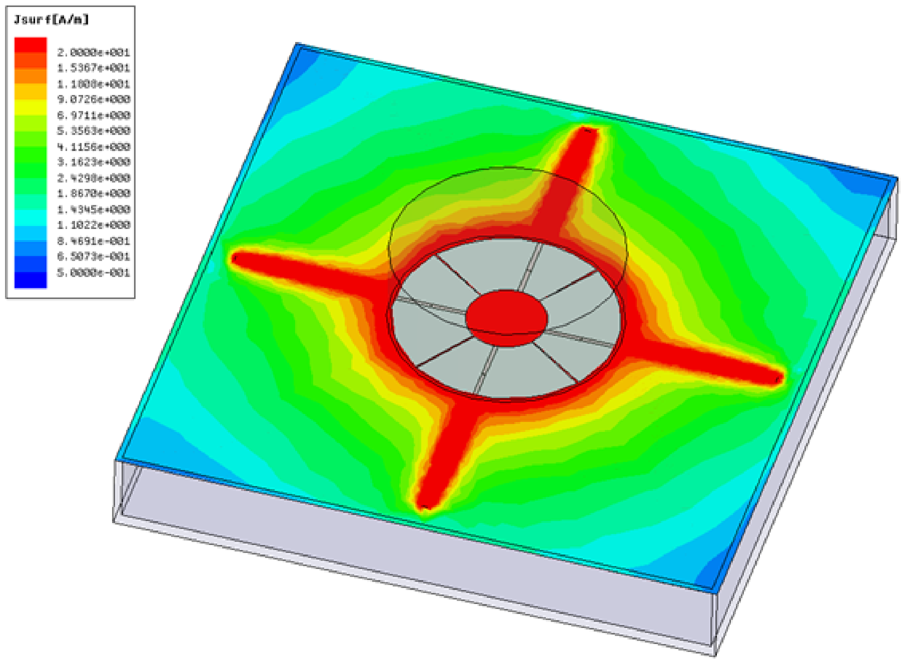
Figure 20: Hybrid DRA (a) reflection coefficient and (b) maximum absolute gain, and (c) axial ratio as a function of the ground plane size.

The current distribution on the ground plane has been simulated at 1.15, 1.4 and 1.6 GHz for a 100 x 100 mm^2 ground plane (Figure 21). One can notice that the current distribution is centered on the ground plane and it is more compact at 1.6 GHz compared to lower frequencies. This can be explained by the fact that the slots are resonant in the lower part of the frequency band, and also the ground plane is electrically smaller at 1.15 GHz compared to 1.6 GHz.

a) 1.15 GHz



b) 1.40 GHz



c) 1.60 GHz

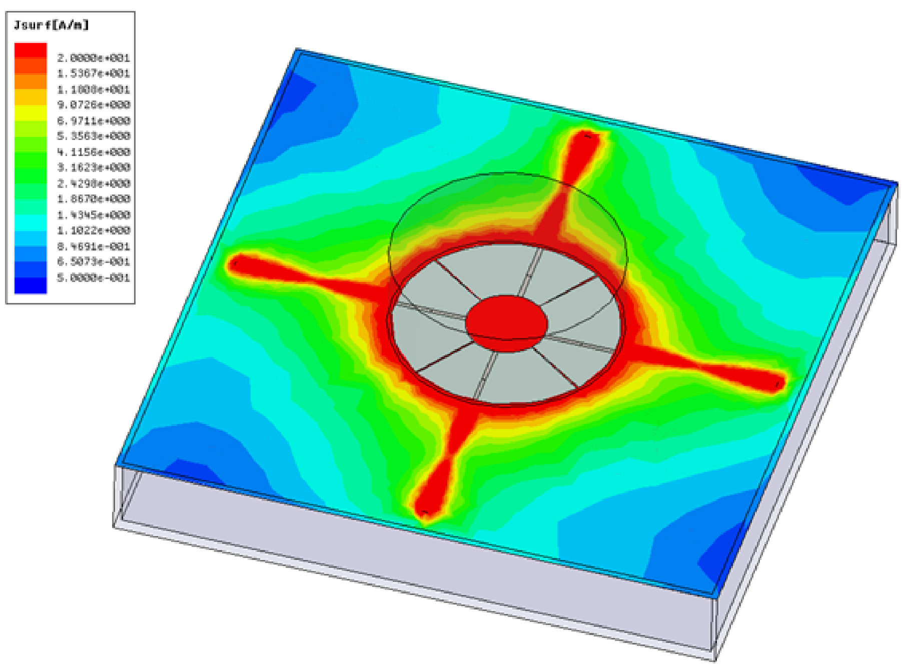


Figure 21: Current distribution on the antenna ground plane as a function of the frequency.

4 Conclusion and perspectives

A miniaturized wideband circularly polarized hybrid dielectric resonator antenna has been designed and it exhibits performances comparable to its non-miniaturized version. The antenna surface, including the ground plane, is 100x100 mm^2 and its height considering the back plate housing is 35 mm. It is relatively easy to design and fabricate. The radiating element is composed of small cylinder of high dielectric material, glued on a single layer of substrate material supporting the arc slots and the feeding system. The fabricated antenna exhibits a good impedance matching from 1.22 to 1.71 GHz (33% bandwidth) thus covering the complete GNSS frequency band. The achieved gain is over 0 dBic and the axial ratio (AR) is lower than 2 dB at boresight over the 1.25-1.63 GHz frequency band. The half-power beamwidth larger than 95^o, and the AR beamwidth (AR < 3 dB) is larger than 130^o. Good agreement has been observed between the simulated model and measurement of a fabricated prototype. A slight frequency shift has been noticed and an analysis showed that it is mainly attributed to the presence of an air gap between the dielectric resonator and the ground plane. This miniaturized CP H-DRA design offers comparable operating frequency bandwidth, gain and axial ratio to the original design. To the knowledge of the authors, this is the only antenna of this size that covers the complete GNSS frequency bandwidth with such excellent overall characteristics [8], [9].

As for perspectives, it would be worthwhile to measure the antenna again using a different glue to bond the dielectric resonator to the ground plane to try to reduce the air gap. If the air gap can be avoided, then it would be possible to investigate further the cause of the observed frequency shift. Another solution will consist of considering the air gap when optimizing the antenna design. Also, a study must be carried out to identify techniques that could contain currents on the ground plane to a smaller area. Finally, the performance of the proposed hybrid DRA must be assessed in an array configuration.

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List of symbols/abbreviations/acronyms/initialisms

DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
R&D	Research & Development
AR	Axial Ratio
CP	Circular Polarization
DR	Dielectric Resonator
DRA	Dielectric Resonator Antenna
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
H-DRA	Hybrid Dielectric Resonator Antenna
HPBW	Half-Power BeamWidth
PCB	Printed Circuit Board
VSWR	Voltage Standing Wave Ratio

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This document reports on a compact circularly polarized hybrid dielectric resonator antenna (DRA) operating over the entire Global Navigation Satellite Systems (GNSS) frequency band, which includes the GPS, Galileo and GLONASS frequency bands. The proposed design is composed of a small cylinder of ceramic, a single layer substrate material and a back plate housing, and is therefore relatively easy to fabricate. The used concept consists in 4 sequentially rotated arc-shaped slots etched in the ground plane, which radiate in the lower part of the frequency band and feed the DRA in the upper part. This antenna was fabricated and characterized. It exhibits a good impedance matching from 1.22 to 1.71 GHz (33% bandwidth) thus covering the complete GNSS frequency band. The achieved gain is over 0 dBic and the axial ratio (AR) is lower than 2 dB at boresight over the 1.25-1.63 GHz frequency band. The half-power beamwidth larger than 95^o, and the AR beamwidth (AR < 3 dB) is over 130^o. Despite a slight frequency shift observed during the measurements, a good agreement was noted with the simulation. The antenna surface, including the ground plane, is 100x100 mm^2 and its height considering the back plate housing is 35 mm. To the knowledge of the authors, this is the only antenna of this size that covers the complete GNSS frequency bandwidth with such excellent overall characteristics.

Le présent document décrit une antenne à résonateur diélectrique (ARD) hybride à polarisation circulaire fonctionnant sur toute la bande fréquentielle des systèmes de navigation par satellites (GNSS, Global Navigation Satellite Systems), notamment dans les bandes de fréquence GPS, Galileo et GLONASS. La géométrie proposée est relativement facile à fabriquer. Elle comprend un petit cylindre en céramique de forme élémentaire, une couche de substrat et un boitier métallique. Le concept utilisé repose sur 4 fentes en forme d'arc gravées dans le plan de masse du substrat et disposées en effectuant une rotation séquentielle. Ces 4 fentes rayonnent dans la partie inférieure de la bande de fréquence de l'antenne, tandis qu'elles alimentent l'ARD dans la partie supérieure de la bande de fréquence. Cet élément rayonnant a été fabriqué et caractérisé. Une bonne adaptation d'impédance a été observée entre 1.22 et 1.71 GHz, soit 33% de bande passante. Le gain obtenu est supérieur à 0 dBic et le taux d'ellipticité (TE) est inférieur à 2 dB dans l'axe sur la bande de fréquence 1.25-1.63 GHz. L'ouverture à mi-puissance est supérieure à 95^o, et l'ouverture pour un taux d’ellipticité inférieur à 3 dB est supérieure à 130^o. Malgré un faible écart en fréquence noté au cours des mesures, un bon accord avec la simulation a été observé. La surface de l'antenne est de 100x100 mm^2 en incluant le plan de masse, et sa hauteur est de 35 mm. À la connaissance des auteurs, il s’agit de la première antenne de si petite taille couvrant entièrement la bande fréquentielle GNSS avec de telles performances.

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