# Miniaturized DRA Array for GNSS Applications

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***Abstract*—The increase in GNSS satellites and services is fostering a new wave of applications related to satellite navigation. Such increase is also followed by more and more threats, aiming at signal disruption. In order to fully exploit the potentialities, being able at the same time to counteract threats such as interference and jamming, smart antenna systems are being developed worldwide, with the requirements of multi-band operation and compactness. In order to answer such need, the present work proposes a miniaturized 2x2 array able to operate at E5, L2, E6 bands, with an overall footprint of only 3.5" (89 mm), by means of dielectric resonator antenna (DRA) technology.**

***Index Terms*—GNSS, array, miniaturization, DRA**

## I. Introduction

The increase in GNSS constellations and services alongside with the GPS system, as for instance the forthcoming Galileo system, enables a plethora of novel applications for what concerns the precise positioning of people, vehicles and goods. Such spreading of satellite navigation applications also causes more and more interest in malicious attacks, for instance through jamming or spoofing, to deny the service [1] or even work to deceive about the navigation functionality [2].

In order to fully exploit the offered possibilities and at the same time counteract possible threats, high-performance systems, able to steer the antenna pattern and hence place nulls against interferences and maxima at the DOA of signals, are being developed all over the world, e.g. [3]. These new systems might be particularly useful in mobile applications, such as aircrafts or vehicles, where precise localization can play an important role. However, the canonical dimensions of the antennas, as well as of receivers, do not fit with the requirements of low-profile and low weight, typical of mobile applications: there is hence a need for miniaturization both of the single radiator and of the overall antenna array, to enable real-life implementation of the developed systems.

Moreover, benefits can be easily foreseen if antennas and receivers are able to process at the same time signals coming from multiple bands, with increases in precision, availability and robustness.

The present work shows a design for a miniaturized GNSS 2x2 array (overall footprint dimension: 3.5 inches) for E5/L2/E6 bands operation. The single antennas are dielectric resonator antennas (DRAs) and are made of high dielectric constant (DK) bulk glass ceramic materials, enabling good miniaturization. Special measures are taken in order to minimize mutual coupling between the very close radiators. The paper is divided as follows: Sec. II shows the single antenna design, while array design is explained in Sec. III. Finally, conclusions are drawn in Sec. IV.

## II. Single Antenna Design

Dielectric resonators (DRs) [4] have been thoroughfully analyzed in literature and used for various applications, beginning with microwave filters and oscillators. They have the characteristic property of having very few metal parts and hence exhibit quite low conductor losses even at very high frequency. Thanks to such feature, their use as antennas is now becoming popular (because low losses allow high radiation efficiency). Their behaviour is based on the resonant mode(s) established in a dielectric material by a feeding element. Such mode will however not be totally confined into the dielectric material, but will also leak out, leading to radiation properties.

By using dielectric resonator antennas (DRAs) [5], two positive effects are generated: on the one hand, they usually make use of very high DK dielectric materials, hence enabling strong miniaturization, as the resonant frequency depends from the dimension and the DK of the DRA. On the other hand, they are not planar, but volume structures and hence give designers additional degrees of freedom during the design phase as well as allow for larger bandwidths.

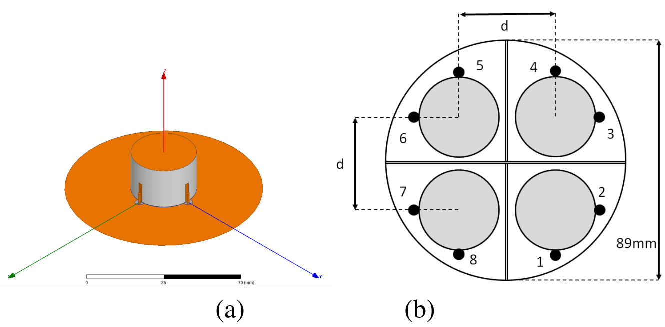


Figure 1. 3D view of the single DRA (a) and scheme (with all ports denomination) of 2x2 DRA array with metallic fence (b) on a circular ground plane (diameter: 3.5").

In the present work, a bulk glass ceramic material with a DK of about 30 has been taken in consideration for the DRA. The antenna has a cylindrical shape and is placed on a 3.5" metallic plate. The feeding is obtained by means of two probes, tangential to the DRA surface on two 90°-shifted positions, to excite RHCP fields. The cylindrical probes are soldered to a copper strip, conformal to the cylinder, acting as tuning element. Moreover, the upper surface of the cylinder is fully covered by copper, helping in further miniaturization (Fig. 1 (a)).

The single antenna element has a diameter of 30.5 mm and a height of 20 mm and achieves a realized gain as depicted in

Fig. 2. As it can be observed, the single antenna has optimal performance at L2 band, i.e. in the middle of the frequency range covering also E5 and E6 bands. At $f = 1228$ MHz, the realized gain is 4.5 dBic.

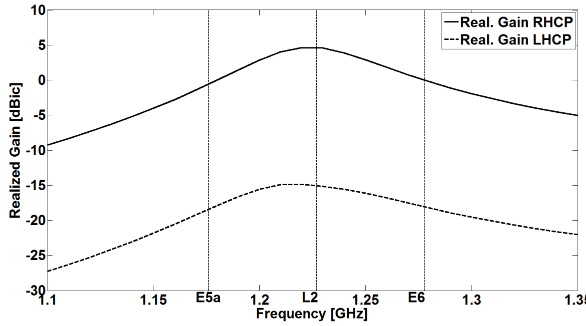


Figure 2. Boresight realized gain of the single DRA on a circular ground plane (diameter: 3.5")

## III. Array Design

The single antenna shown in the previous Section has been used as "building block" for the array. The antennas have been positioned following a sequentially rotated geometry, in order to help in improving polarization purity of the overall array. A schematic view of the array, with ports naming, is shown in Fig. 1(b). Metallic fences are placed between the antennas, to limit the mutual coupling effects, due to the very close vicinity of antennas (mutual distance d= 37 mm $\approx$ $\lambda/7$ at E5 band).

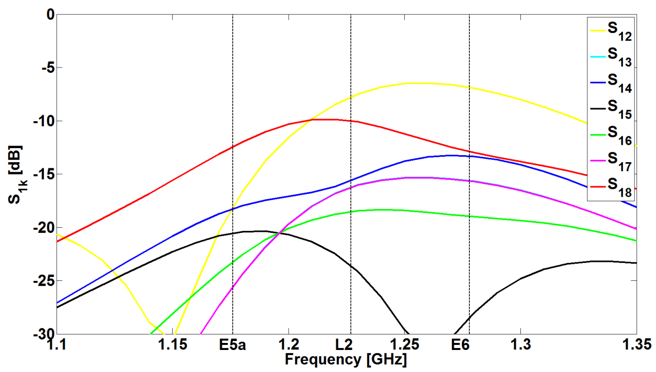


Figure 3. $S_{1k}$ parameters of the optimized DRA array

The positive effect of fences in reducing mutual coupling can be seen in Fig. 3, where mutual S parameters for port 1 are shown: all mutual S- parameters are below -10 dB, apart from $S_{12}$, which expresses the power flow between the two probes (Fig. 1-b) of the same antenna and where obviously the fence does not manage to decrease the coupling. For comparison sake, $S_{12}$ would not change much if no fences were present, while $S_{18}$ would become ~ -2dB, thus much worse than in the configuration with fences.

The realized gain of the 2x2 array, both for the embedded case, where only one antenna is fed, and the array case, where all antennas are fed uniformly, is shown in Fig. 4. Due to the close vicinity of the antennas as well as the disturbing effect of the metallic fences on the radiation properties, the embedded radiation has, as is to be expected, lower gain values and a higher cross-polarization than the single antenna.

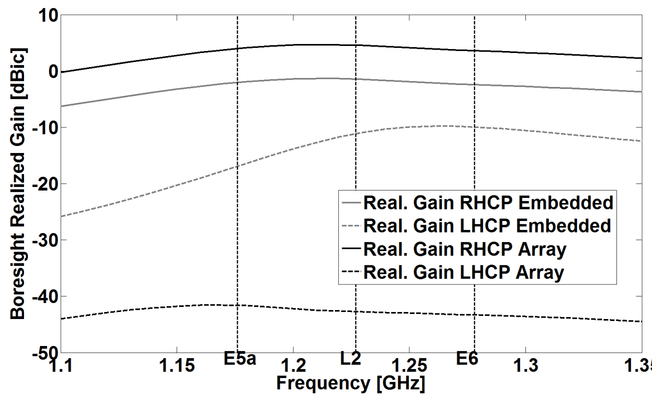


Figure 4. Boresight realized gain of the 2x2 array of DRAs for the embedded case (only antenna 1 fed) and the array case (all antennas fed uniformly)

However, thanks to the sequential rotation strategy, the cross-polarization in the array mode is strongly suppressed (Fig. 4). The gain of the array achieves a very good 3-dB-bandwidth, including all E5/L2/E6 bands and hence enabling multiple band processing.

Comparison with measurement will be shown during the conference.

## IV. Conclusions

A miniaturized 2x2 array, made of dielectric resonator antennas, for robust GNSS navigation at E5/L2/E6 band has been shown. The use of a high DK material enables good miniaturization, helping to pack the 2x2 array in a footprint of 3.5" (= 89 mm). Metallic fences are used to decrease mutual coupling due to the close vicinity of the antennas and sequential rotation is employed to improve the polarization purity of the array.


## V. Acknowledgments

The author wishes to thank Dr. M. Letz from SCHOTT AG for valuable support with the dielectric material, as well as W. Elmarissi and G. Buchner for their help in measurement.


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