A Multi-Band Conformal Antenna Array for GNSS Applications

Kazeem A. Yinusa, Wahid Elmarissi, Stefano Caizzone and Achim Dreher
German Aerospace Center (DLR)
Institute of Communications and Navigation
Oberpfaffenhofen, Wessling 82234, Germany
Email: kazeem.yinusa@dlr.de

***Abstract*—The position accuracy in satellite navigation is enhanced when low elevation satellites are included in the triangulation due to the contribution of satellite geometry. Moreover, improved reception of low elevation signals leads to a higher overall system availability. However, the receiving antenna characteristics usually suffer from low-gain and high axial ratios at low elevations. In this contribution, an antenna array conformal to a spherical cap is presented. The array consists of a single antenna on top of the cap and six, radially directed, equally spaced elements on a ring. The manufactured antenna achieves a gain between 0 dB and 4 dB with low axial ratio in the forward hemisphere at the E5a/b and E1 center frequencies of 1.176 GHz, 1.207 GHz and 1.575 GHz, respectively.**

I. Introduction

Microstrip antennas are widely used in global navigation satellite systems (GNSS) due to their low cost, low profile and their light weight properties [1]. The design parameters of GNSS antennas usually include the gain and axial ratio performance. The former is important since satellite signals are very weak when they arrive at the receiving terminal. The latter is essential for the antenna to differentiate between the right hand circularly polarized (RHCP) direct satellite signals from the multipath signals which are predominantly of left hand circular (LHC) or mixed polarization. Both the gain and axial ratio performance of most antennas are not ideal at low elevations. Signal reception at low elevation is, however, important as it results in a better geometrical dilution of precision and can also improve the total system availability as more satellites become useable. Also, due to the upcoming GNSS constellations such as the European Galileo and the Chinese BeiDou systems, antennas that are resonant at multiple frequency bands are receiving increasing attention. In this contribution, a multi-band antenna array conformal to a hemispherical cap is presented. The array consists of one element on top of an aluminum cap and six other antenna elements arranged on a ring below the top element. The antenna array is resonant in multiple frequency bands including the GPS L1 and L5 frequency bands with adequate bandwidths that extend to the Galileo E5a, E5b and E1 frequency bands. The shape of the array allows it to achieve relatively good performance in terms of gain and axial ratio over a complete hemisphere.

II. Antenna Design

The single element design consists of a stacked patched configuration in order to achieve the required multiple resonant frequencies [2], [3]. The optimized dimensions are shown in Fig. 1. The antenna utilizes a substrate with dielectric constant of 10.2 and a thickness of 1.27 mm for the uppermost layer and 2.54 mm for the remaining three layers of substrates. Circular polarization is achieved by introducing a $90°$ phase shift between the output feeds by means of a commercial hybrid coupler. In order to ensure a physically robust stack-up, the layers of dielectrics are glued together by a thin layer (0.2 mm) of an adhesive material with a dielectric constant of 6.6. The antenna is then enclosed in a metallic cavity in order to reduce mutual coupling with neighboring elements when it is integrated in the array. The measured realized gain of the manufactured antenna is shown in Fig. 2. It can be observed

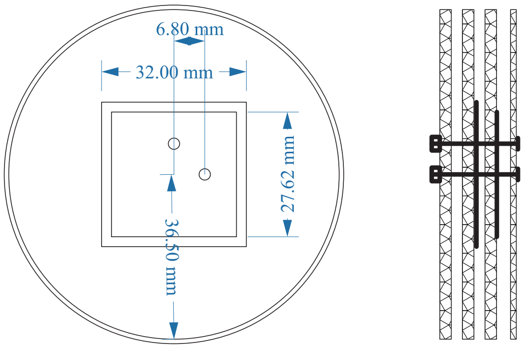

Fig. 1. Design of the single antenna element.

that the antenna achieves a gain of more than 1 dB within the desired E5a,b and E1 frequency bands with an LHCP gain of less than -17 dB. The bandwidth can be further broadened by increasing the diameter of the capacitive caps which are set to 2.5 mm for this design.

III. Array Integration

The array consists of seven antenna elements. The antennas are arranged on a spherical cap made of aluminum with one antenna on top of the cap and six radially directed antennas arranged on a ring similar to the simulated set-up in [4]. The equatorial diameter of the spherical cap is 238 mm. In order

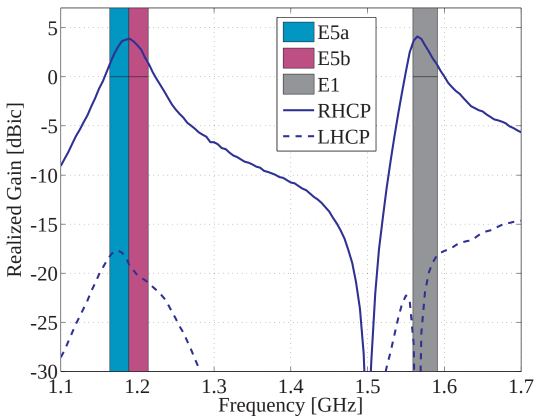

Fig. 2. Measured realized gain of the manufactured single element at boresight.

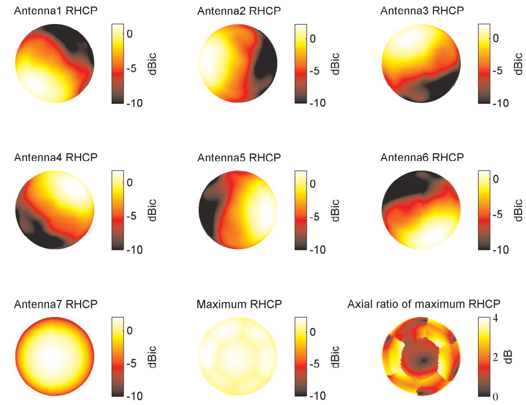

Fig. 4. Embedded RHCP gain patterns of the antenna elements at 1.575 GHz. The maximum RHCP gain with the corresponding axial ratios over the upper hemisphere are also shown. The z-axis is out of the page at the center of each plot.

to achieve an hemispherical coverage, the six antennas on the ring are equally spaced and tilted at an angle of $58°$ from the zenith. The manufactured antenna is shown in Fig. 3.

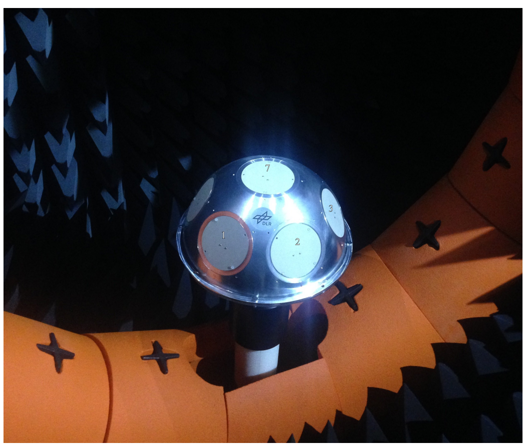

Fig. 3. The conformal antenna array in a measurement chamber at the DLR.

IV. Results

The antenna was measured in an anechoic near-field chamber equipped with a spherical positioner. During the measurement of the embedded patterns, the port of the measured antenna is fed while the remaining antenna ports in the array are terminated by 50 Ohm resistors. Fig. 4 shows the embedded realized gain patterns of the antenna at 1.575 GHz. The "Maximum RHCP" pattern is obtained by choosing the highest value of the RHCP gain from the seven array elements for each far-field direction. The hemispherical coverage of the array is clearly observed from the gain patterns and the corresponding axial ratios. Similar results were obtained for the E5a and E5b frequency bands. The results are summarized in Table I. They are extracted from the maximum RHCP and the corresponding axial ratio patterns at the stated frequencies. The performance of the antenna at low elevation can help to reduce the elevation mask of a GNSS receiver thereby increasing the number of satellites that can be used for positioning. Also, resonance at multiple frequency bands can be useful for multi-constellation positioning and multi-frequency ionospheric corrections.

TABLE I

Measured far-field parameters of the antenna array. Zenith direction coincides with $90°$ elevation and average values over complete azimuth are given for elevation angles other than zenith.

		E5a (1176 MHz)	E5b (1207 MHz)	E1 (1575 MHz)
Realized Gain [dBic]	Zenith	4.66	2.84	2.03
	$44°$ Elev.	2.16	1.93	1.61
	$6°$ Elev.	1.87	1.00	0.65
Axial Ratio [dB]	Zenith	1.83	1.67	0.56
	$44°$ Elev.	3.17	2.73	2.46
	$6°$ Elev.	2.16	2.18	2.86

V. Conclusion

A spherical cap conformal antenna array was presented. The array achieves good gain and axial ratio performance over a complete hemisphere and is resonant at multiple GNSS frequency bands. Such an antenna improves the availability of GNSS signals at lower elevation due to the hemispherical coverage and can take advantages offered by multi-frequency GNSS positioning due to the multiple resonant frequencies.

References

[1] J. Wang, "Antennas for global navigation satellite system (gnss)," *Proceedings of the IEEE*, vol. 100, no. 7, pp. 2349–2355, July 2012.

[2] S. Maci and G. Gentili, "Dual-frequency patch antennas," *Antennas and Propagation Magazine, IEEE*, vol. 39, no. 6, pp. 13–20, Dec 1997.

[3] Z. Wang, S. Fang, S. Fu, and S. Lu, "Dual-band probe-fed stacked patch antenna for gnss applications," *Antennas and Wireless Propagation Letters, IEEE*, vol. 8, pp. 100–103, 2009.

[4] J. Lambert, C. Balanis, and D. DeCarlo, "Spherical cap adaptive antennas for gps," *Antennas and Propagation, IEEE Transactions on*, vol. 57, no. 2, pp. 406–413, Feb 2009.