Polypropylene-Based Array-HIS Antenna for mmWave Imaging Applications

A. Flórez Berdasco[1*], M. E. de Cos Gómez[1], and F. Las-Heras Andrés[1]

[1]TSC Electrical Engineering Dept., Gijon, Spain
[*]corresponding author: florezalicia@uniovi.es

Abstract: A compact and environmentally friendly uniplanar wearable antenna for an assistance system to support visually impaired people is presented. The antenna operates in the mmWave ISM frequency band (24.05-24.25 GHz). Polypropylene was selected as the antenna substrate due to its low-cost, flexibility and environmental advantages. A HIS metasurface has been designed to combine with the basic array antenna. Different unit-cell arrangements have been analyzed and compared. The resulting array-HIS antenna outperforms the basic array antenna in radiation properties and bandwidth.

Mmwave band has attracted a lot of attention since its incorporation into the useful 5G spectrum and the definition of a licensed free ISM frequency band. The non-ionizing characteristic of these frequencies and their ability to pass through clothes, along with the compact size and affordable price of this technology, makes mmWave band a very good option for human safety applications. This work presents an antenna to be used with a radar to avoid collisions.

A compact two-elements array has been designed due to its omnidirectional radiation pattern, which is preferred to illuminate all the scene from each possible position despite its shorter range. A flexible, economical, and eco-friendly material, Polypropylene (PP), has been used for the first time as the antenna substrate at mmWave band (ε_r=2.2, tanδ=0.002, h=0.52mm). Figure 1a) shows the antenna geometry with its parameters. It has been optimized through simulation. The final dimensions are indicated in Table 1. It shows proper impedance matching between 23.5 GHz to 24.6 GHz (4.4 %) (see Figure 1b)). The radiation parameters at 24.1 GHz can be found in Table 2 (A), while the radiation pattern cuts are shown in Figure 1c) and d).

W_{50}	L_{in}	T	W_{100}	L_{100}	T_2	L_{50}	A	L_{50}	T_3	W_m	L_m	W_p	L_p	W	L	h
1.64	8	1.4	0.55	1.2	1.6	0.5	0.2	2.7	1.8	1	1.7	4.7	3.5	26.6	25.5	0.52

Table 1 Dimension of the basic array antenna [mm]

In order to improve the performance of the basic array antenna a High Impedance Surface (HIS) has been designed to be combined with it. A simple squared geometry unit-cell has been selected. HIS behavior is sought in a wide bandwidth, since the resonance frequency will shift when combined with the antenna, as the structure will not be infinite. For this reason, the final dimensions of the metasurface are Wp=2.65mm, g=0.2mm and h=0.52mm. It resonates at 26.4 GHz with a 26.2% bandwidth of HIS performance (see Figure 1f)).

Three different arrangements of the HIS unit-cells with the basic array antenna have been studied. Figure 1g) includes a set of three unit-cells placed between the patches (design (W)) as a kind of wall to reduce the mutual coupling, Figure 1h) incorporates unit-cells surrounding the patches (design (R)) to reduce the potential surface waves and Figure 1i) adds a new row of unit-cells (design (2R)). Table 2 indicates the radiation parameters and the bandwidth for each design. (W) increases the bandwidth and improves the front-to-back ratio (FTBR) with respect to (A) at the expense of slightly reduce directivity and gain. Meanwhile, (R) overcomes (W) and (A) in bandwidth, directivity and gain but with a worst FTBR. In addition, (2R) presents better FTBR value, keeping directivity, gain and practically the same bandwidth with respect to (R), but the total size of the design has increased. However, (2R) outperforms the basic array with the same size (A*) in both, bandwidth and radiation properties. The previous analysis is reinforced by the surface currents shown in Figure 1e) g) h) and i), where it can be observed that the unit-cells present high surface current levels, especially the central unit-cell between patches, which reduces the mutual coupling between them, enhancing the antenna performance. The basic array performance has been improved, especially in bandwidth by combining with a HIS. Depending on the application, the combined structure should be optimized to obtain suitable radiation properties.

Design	BW [%]	D [dB]	G [dBi]	η [%]	FTBR [dB]	Ypos [mm]	Fr HIS [GHz]	Area [mm²]
(A)	4.4	9.6	9.5	98	18.3	-	-	678.3
(W)	5.4	9.2	9.1	98	21	1	26.4	678.3
(R)	6	9.9	9.9	100	12.2	1	26.4	678.3
(2R)	5.8	9.9	9.8	98	14.6	0.5	26.4	731.5
(A*)	4.6	9.7	9.5	95	14.8	-	-	731.5

Table 2 Comparison of the designs. Radiation properties (at 24.1 GHz) and bandwidth.

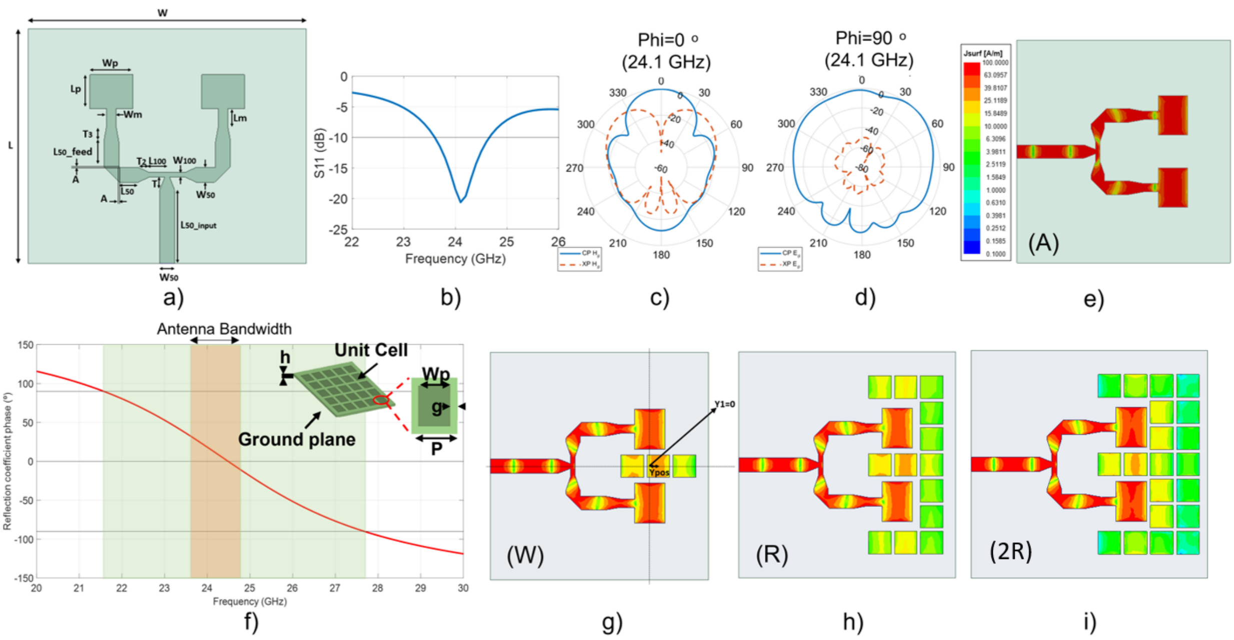

Figure 1 a) Antenna geometry b) Reflection coefficient c) H-plane d) E-plane e) Surface current of the (A) design f) HIS bandwidth and unit-cell geometry g) Surface current of the (W) design h) Surface current of the (R) design i) Surface current of the (2R) design.

Acknowledgement

Funded by the Ministerio de Ciencia e Innovación of Spain under the FPI Grant PRE2019-089912 and project MILLIHAND RTI2018-095825-B-I00, and by Gobierno del Principado de Asturias under project IDI/2021/000097.

References

1. Tero Kiutu et al, “Assistive device for orientation and mobility of the visually impaired based on millimeter wave radar technology—Clinical investigation results,” Cogent Engineering, Vol. 5, 2018.
2. J. Seifallah et al, “Compact mmWave FMCW radar: Implementation and performance analysis,” Journal Title Abbreviation, Vol. 34, 34–36, 2019.
3. M. E. de Cos et al, “Polypropylene-Based Dual-Band CPW-Fed Monopole Antenna,” IEEE Antennas and Propagation Magazine, Vol. 55, No. 3, 264-273, 2013.