Modified Design and Fabrication of a broadband Millimeter-Wave Ankh-Key Antenna for 5G and Next Generations Applications

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Ashraf A. M. Khalaf
Minia University

Modified Design and Fabrication of a broadband Millimeter-Wave Ankh-Key Antenna for 5G and Next Generations Applications

N. M. Rashad
Communication and Electronics Department, Faculty of Engineering
October University for Modern Sciences and Arts, MSA
Giza, Egypt
nrashad@msa.eun.eg

Ashraf A. M. Khalaf
Electronics and Communication Department, Faculty of Engineering
Minia University
Minia, Egypt
ashkhalaf@yahoo.com

***Abstract*— Recently, researches and industries are moving toward new technologies. A modified Ankh Key microstrip antenna is designed, fabricated and measured to work in K_a, V, W and G bands enhancing the use of 5G and next generation applications. The Multiband antenna can operate in the 28 GHz, 37GHz, 60 GHz, 80GHz, and beyond 140 GHz bands with peak gain between 6.3 dBi – 10.25 dBi along the operating spectrum making it possible for use in various applications. The low cost single layer antenna was simulated and results were compared using HFSS and CST softwares showing promising results.**

***Keywords*— 5G, 6G, 7G, Microstrip, Antenna, Millimeter wave, Multi-band, HFSS, CST.**

I. Introduction

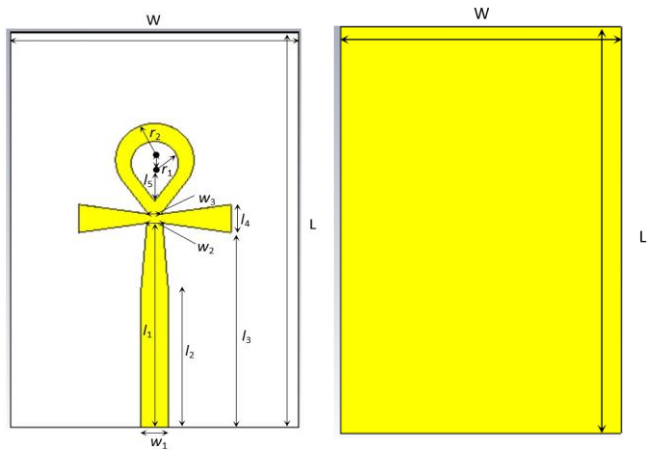
The Millimeter wave bands extend from 30-300 GHz providing up to multi- Gega bytes data transfer challenging researchers to work in this field. In October, 2015, FCC assigned the frequency bands 28GHz, 37GHz, 39GHz, 47GHz, and 64-71 GHz for wireless broadband (FCC 15-138). In March, 2019, FCC opened the Terahertz wave spectrum, from 95 GHz – 3 THz, unlicensed for experimental use to let engineers dreaming of the next generation of wireless start their work (FCC 19-44) [1,2].

In this paper, a modified Pharaonic Ankh Key antenna with different scales and dimensions enhancing wider bandwidth and better performance than the previously proposed ankh key antenna [3]. The old proposed antenna has dimensions of 7.5 x 7.5 x 0.508 mm^3 operating in the frequency range between 60.5 GHz and 72 GHz only with peak gain 8.3 dBi. The dimensions of the new single layered antenna are 12.75 x 18.7 x 0.787 mm^3 which was simulated and compared using two different simulators, HFSS and CST, showing very convenient results. Rogers 5880 substrate was used, as with the previous antenna, with ε_r = 2.2 and tan δ = 0.0009. The antenna has multi-resonating frequencies and a huge bandwidth extending from 26.5 GHz till beyond 140 GHz with some band-notches and maximum gain between 6.3 dBi and 10.25 dBi.

The antenna is designed to meet the same structure of a typical Pharaonic Ankh Key which has tapered feeding line, bow-tie structure, curved edge and a slot which are the main characteristics of an antenna to achieve wide bandwidths. Thus, the antenna can operate in the following band; 26.5 GHz – 28.8 GHz, 35.5 GHz – 45.7 GHz, 52.5 GHz – 85.3 GHz, 90.6 GHz – 95.4GHz, 97.6 GHz – beyond 140 GHz.

II. Design Geometry

Fig. 1 shows the geometry of the proposed single patch microstrip Ankh Key antenna with a full ground structure of dimensions 12.75 x 18.7 mm^2 and overall patch dimensions of 14.4 x 6.74 mm2 fed with a 50 Ω microstrip line of length l_2 = 6.46 mm and w_1 = 1.21 mm then tapered to reach w_2 = 0.69 mm.



(a) (b)

Fig. 1. Geometry of the proposed antenna; (a) Microstrip patch , (b) Ground.

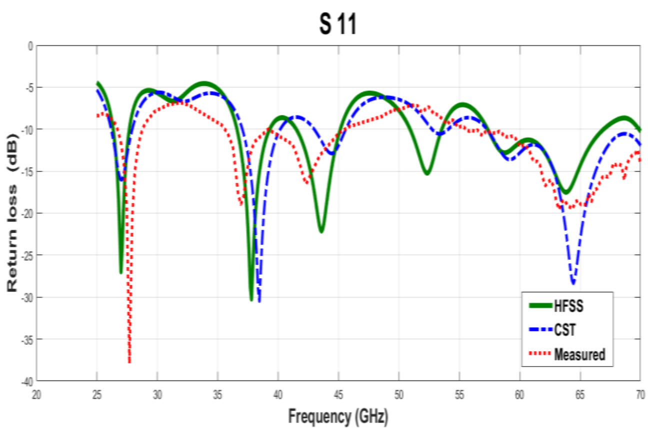
TABLE I. Parameters of the proposed antenna

Parameter	l_1	l_3	l_4	l_5	w_3	r_1	r_2
Dimension (mm)	9.67	9.22	1.33	1.78	0.55	1.04	1.73

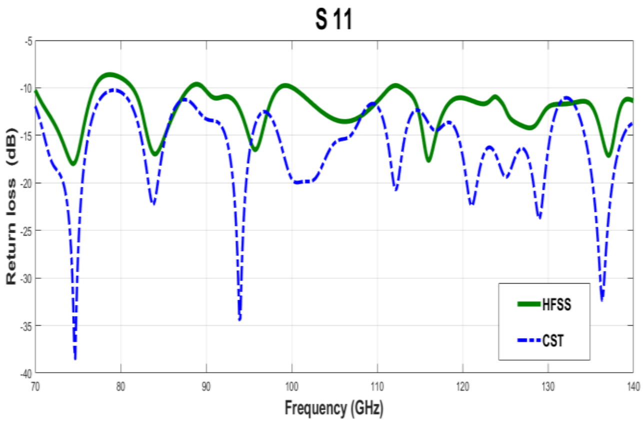
A height h = 0.787 mm of Rogers Duroid RT 5880 dielectric substrate having relative permittivity $\varepsilon_r = 2.2$ and loss tangent $\tan\delta = 0.0009$ is used and the copper thickness mt = 0.035 mm is considered in the calculations.

III. Results and Discussions

The antenna is simulated using HFSS and CST simulators where each has different solving techniques; Finite Element Method (FEM) and Finite Difference Time Domain (FDTD), respectively. Then the antenna was fabricated using photolithographic technique and the return loss was measured with the only available ZVA 67 Vector Network Analyzer of range 10 MHz to 67 GHz, could be extended to 70 GHz. Also, due to lack of facilities, the antenna was connected to a 40 GHz SMA connector with Vector Network Analyzer device, thus the curve of the measuring results is not smooth beyond 40 GHz. All the results were compared together showing a very good agreement especially in the range between 25 GHz – 40 GHz, maximum of the used SMA connector, indicating that the results are very promising. Fig. 2 and Fig. 3 show comparative results of the return loss and peak gain, respectively, for the simulated and measured results. Fig. 2 shows that in the HFSS simulation, the antenna can operate in the bandwidth ranges between 25.3 – 27.7 GHz, 36.5 – 39.5 GHz, 41.5 – 45.1 GHz, 51 – 53.5 GHz, 57.5 – 67.4 GHz, 70.2 – 77 GHz and 81.5 GHz to beyond 140 GHz resonating at 27 GHz, 38 GHz, 43.6 GHz, 52.5 GHz, 58.7 GHz, 64.1GHz, 74.5 GHz, 84 GHz, 95.8 GHz, 106.5 GHz, 116 GHz, 127.8 GHz and 137.1 GHz whereas in the CST simulations, the ranges are between 26.3 – 28.5 GHz, 36.5 – 41GHz, 43.8 – 46 GHz and 57.5 GHz to beyond 140 GHz resonating at 27.3 GHz, 38.4 GHz, 44.5 GHz, 53.2 GHz, 59.5 GHz, 64.4 GHz, 74.2 GHz, 84 GHz, 93.5 GHz, 101.2 GHz, 111.2 GHz, 1118.9 GHz, 120.8 GHz, 125.8 GHz, 128.8 GHz and 136.4 GHz. Although, the measuring results show that the antenna can operate in ranges between 26.5 – 28.8 GHz, 35.5 – 45.7 GH and 55.4 to beyond 70 GHz resonating at 28 GHz, 37 GHz, 42.5 GHz and 63.5 GHz, thus, the antenna is very suitable for 5G and future generations wireless applications. Fig. 3 (a) and (b) shows the maximum gain at the low and high frequencies respectively. The peak gain at the resonating frequencies are between 6.3 dBi and 10.25 dBi which is considered very high gain compared to other single element antennas.

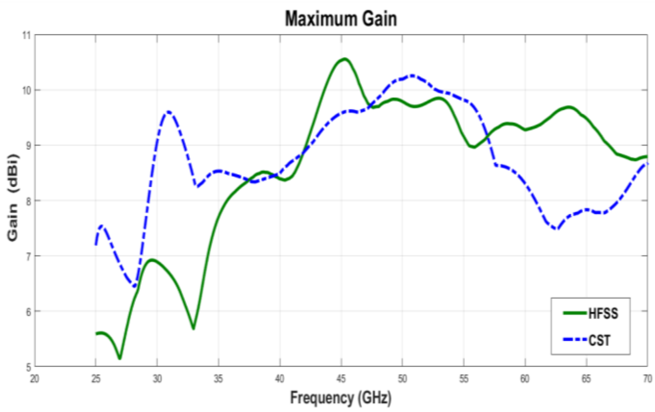


(a)

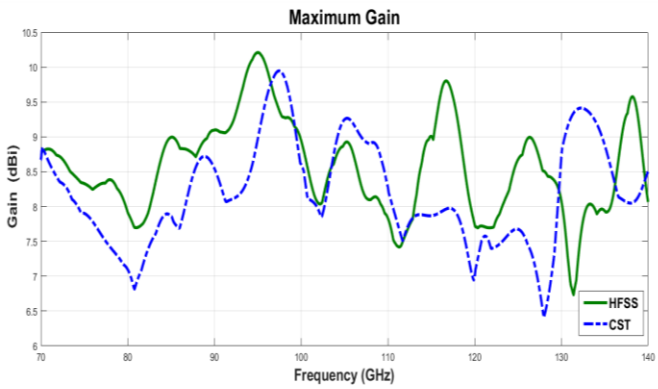


(b)

Fig. 2. Simulated and measured Return Loss; (a) Range 20 GHz – 70 GHz , (b) Range 70 GHz – 140 GHz.



(a)



(b)

Fig. 3. Similated Peak Gain; (a) Range 20 GHz – 70 GHz , (b) Range 70 GHz – 140 GHz.

Fig. 4 shows the fabricated antenna patch and ground. The antenna was easily fabricated using photolithographic technique with very cheap price due to its simple design.

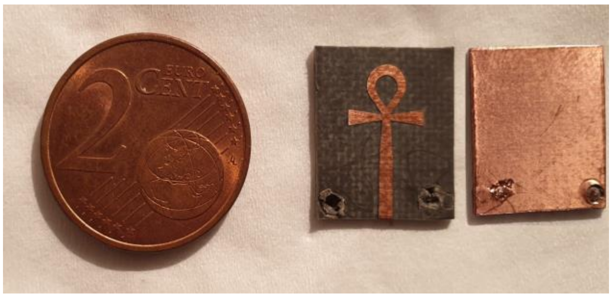
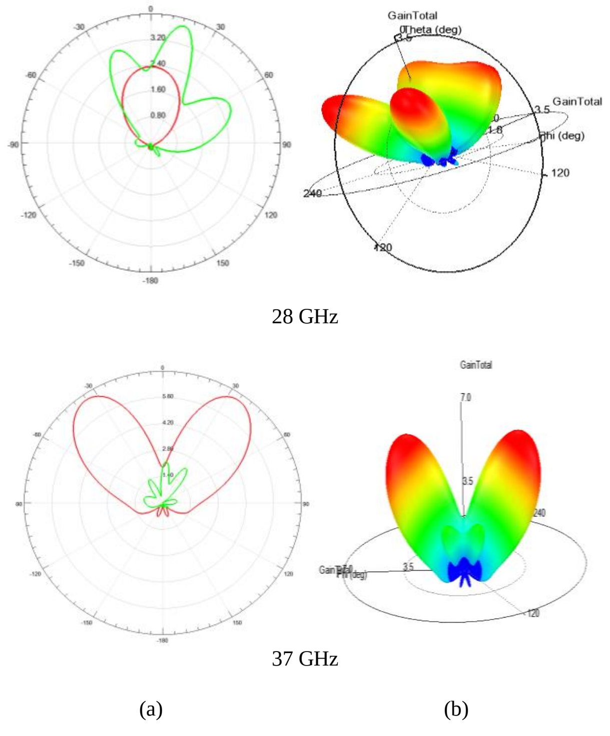
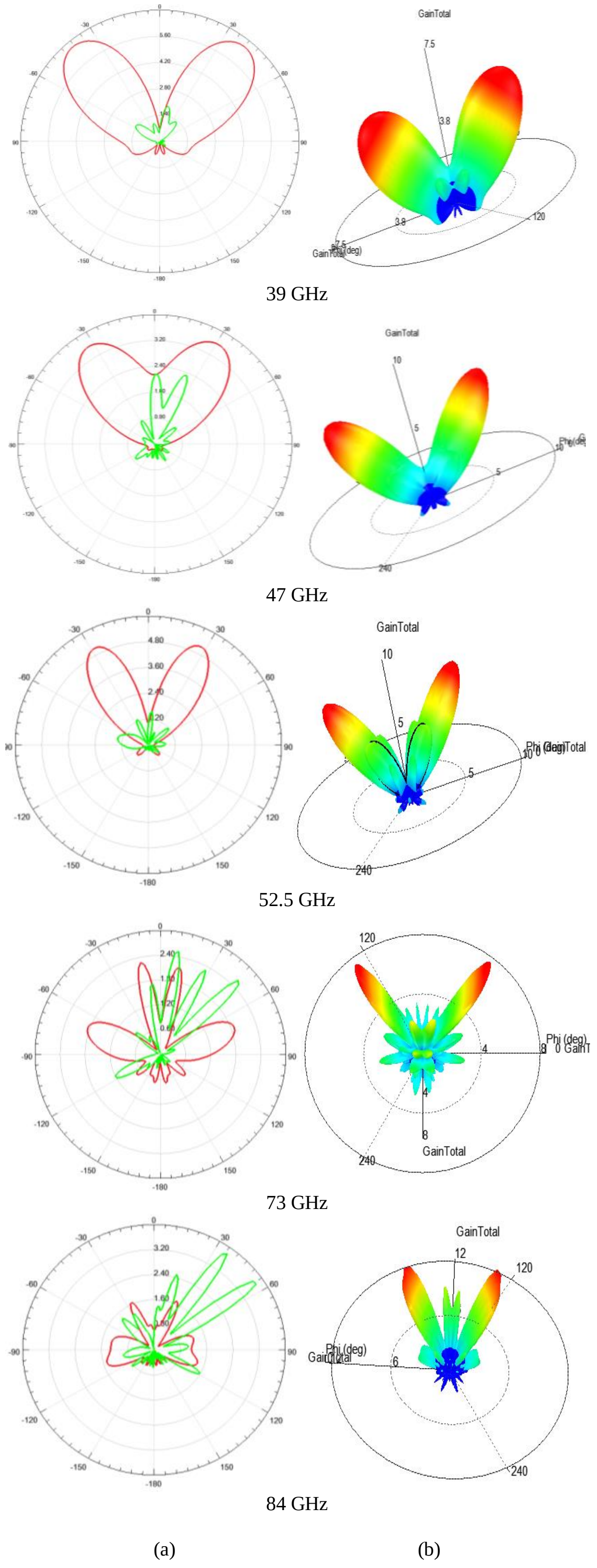


Fig. 4. Fabricated antenna.

Fig. 5 shows the radiation pattern in E-plane and H-plane at different resonating frequencies which are stated in the figure, and the 3D patterns indicating the peak gain for each. In the low and mid frequencies, the radiation pattern has two main directive lobes which can be suitable for use in many wireless applications, but in the high frequencies there are many lobes which can be improved in future modification to meet the required criterion of next generation applications.





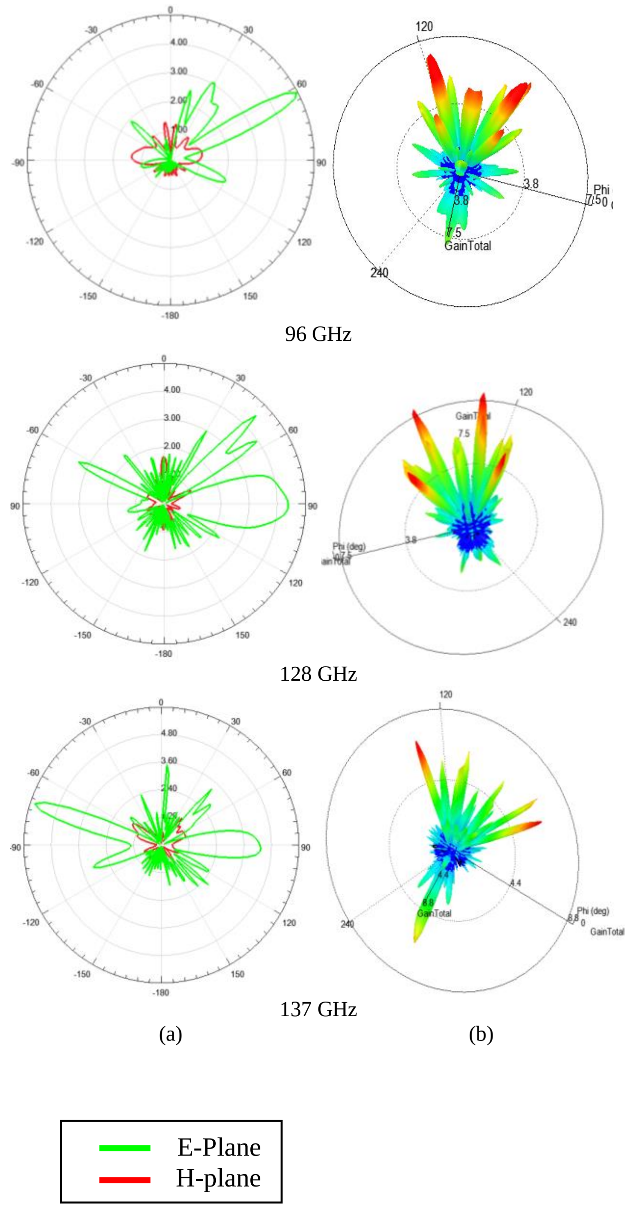


Fig. 5. (a)Simulated E-plane and H-plane at different frequencies , (b) 3D Radiation Pattern

Last but not least, the proposed ankh-key antenna is modified to enhance wider bandwidth and better performance with higher gain allowing it to be used in various 5G applications as well as next generation applications. Table II shows a comparison between the pharonic ankh- key antenna [3] and the modified one with respect to size, bandwidth, resonating frequencies, and peak gain.

TABLE II. COMPARISION BETWEEN ANKH-KEY ANTENNA AND MODIFIED ANKH-KEY ANTENNA

Antenna Characteristics	Pharaonic Ankh-Key Antenna	Modified Pharaonic Ankh-Key Antenna
Size (mm)	7.5 x 7.5 x 0.508	12.75 x 18.7 x 0.787
Bandwidth (GHz)	60.5 - 72	26.3 – 28.5 , 36.5 – 41, 43.8 – 46 , 57.5 to beyond 140
Resonating Frequencies (GHz)	67	28 , 37 , 42.5, 63.5, 74.2, 84, 93.5, 101.2, 111.2, 1118.9, 120.8, 125.8, 128.8 and 136.4
Peak gain (dBi)	8.4	10.25

CONCLUSION

In this paper, a modified pharaonic ankh key antenna of dimensions 12.75 x 18.7 x 0.787 mm^3 is simulated and fabricated resulting in a huge bandwidth extending from 26.6 GHz till beyond 140 GHz with few band notches having a peak gain 10.25 dBi which can be used in various applications of 5G, 6G and maybe 7G technologies.

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