International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 3, March-April 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Design and Simulation of Different Microstrip Patch Antennas' Geometries for 5G Network Frequency Compatibility

Adewumi A. S[1], Azeez I. A[2], Àlàgbé G. A[1], Abolade R. O[3]

[1]Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[2]Department of Physics, Emmanuel Alayande College of Education, Oyo, Nigeria
[3]Department of Electrical and Electronic Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria

ABSTRACT

This paper presents the results of the designed and simulated microstrip patch antennas geometries at 5G network frequency band. The microstrip patch antennas geometries namely circular, rectangular, and square were designed using CST Microwave Studio software and simulated at 5.3 GHz and 7.5 GHz. The performance of the designed antenna parameters, specifically; gain, directivity, Power radiated, and antenna efficiency were evaluated for the patch geometries. The result of the simulation showed that the designed rectangular microstrip patch antenna has the best performance metrics of the three compared patch geometries at 5G network frequency band.

KEYWORDS: *Microstrip, patch, Gain, Directivity, Efficiency*

How to cite this paper: Adewumi A. S | Azeez I. A | Àlàgbé G. A | Abolade R. O "Design and Simulation of Different Microstrip Patch Antennas' Geometries for 5G Network Frequency Compatibility" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-3, April 2022, pp.1972-1977, URL: www.ijtsrd.com/papers/ijtsrd49410.pdf

IJTSRD49410

I. INTRODUCTION

Generally, Microstrip Patch antennas (MPAs) are antennas of the low profile which can be mounted on a substrate. Low-profile antennas are always required for high-performance applications where size, ease of installation, cost, weight, and performance are constraints. They can be used interchangeably for applications such as mobile radio and wireless communications that have similar specifications [1].They are becoming increasingly useful because they can be printed on circuit boards and have become widespread within the mobile phone market [2]. MPAs are highly in demand because of their enormous benefits like small size, low cost, lightweight but still have some flaws like narrow bandwidth, low efficiency, low gain, surface wave excitation, and poor tolerance control of the dielectric constant at higher microwave frequencies [3,4]. Bandwidth enhancement and size reduction are becoming major design considerations for the practical application of MPAs [5,6]. The MPAs are usually formed from etching a patch of conductive material on a dielectric material also known as substrate. It consists of a very thin metallic patch whose thickness is far lesser than the free–space wavelength (figure 1).The antenna is designed so that the maximum radiation pattern is normal to the patch [1]. The objective of the paper is to simulate and compare the performances of MPAs at 5G frequency band using Rectangular, Circular, and Square geometries so as to present the most compatible and efficient geometry for 5G frequency applications.

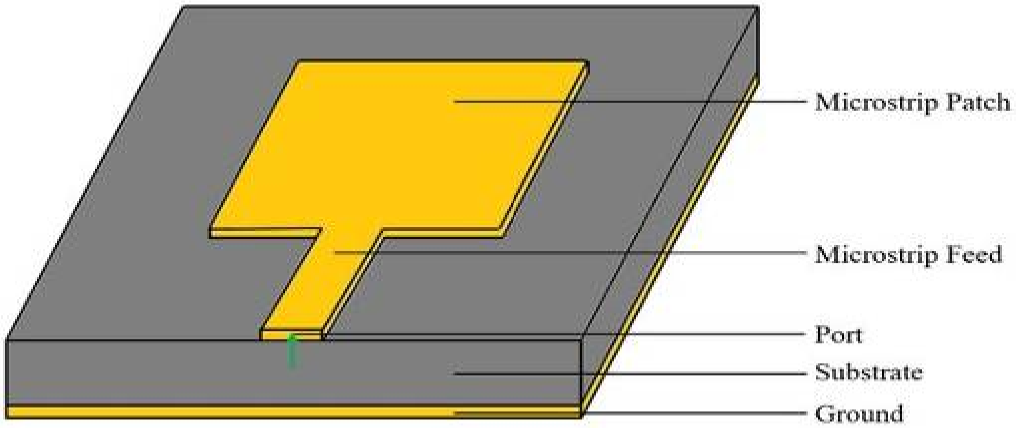


Figure 1: Microstrip Patch Antenna design [7]

II. Materials and Method

To evaluate the performance of the patch geometries, single element circular, rectangular and square patch antennas were designed and simulated using CST Microwave studio. FR4 epoxy, with a dielectric constant of 4.3 and thickness of 1.6 mm was used as the substrate while pure copper with a thickness of 0.035 mm was used as the material for the conducting elements (patch and ground) of the antennas and was fed using microstrip feed line technique. The single element antenna geometries were simulated at 5G frequencies of 5.3 GHz and 7.5 GHz.

III. Microstrip Patch Antenna Geometry Design

According to [8], the width of the rectangular patch was calculated using:

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Also, the length L of the rectangular patch was calculated using [9]:

$$L = L_{eff} - 2\Delta L \quad (2)$$

Where,

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (3)$$

and $$\Delta L = \frac{0.412h(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

where,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{1+12\frac{h}{w}} \quad (5)$$

where ΔL is the correction length factor, L_{eff} is the effective length, and ε_{eff} is the effective dielectric constant of the substrate material. The length and width of the substrate were taken to be twice the dimension of the patch length and width respectively. For the square MPA design, the width of the design was taken as the width of the rectangular MPA.

The dimension of the circular patch was treated as a circular loop, so according to [10] the dimension of the circular patch was calculated using:

$$a = \frac{F}{\left[1+\frac{2h}{\pi\varepsilon F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right]^{\frac{1}{2}}} \quad (6)$$

Where F is given as, $F = \frac{8.791\times10^{9}}{f_r\sqrt{\varepsilon_r}}$

The equation (6) does not take into consideration the fringing effect, and since the fringe effect makes the patch electrically larger, thus the effective radius of the circular patch was deduced using;

$$a_e = a\left\{1+\frac{2h}{\pi\varepsilon_r a}\left[ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}} \quad (7)$$

The dimensions of the designed MPAs geometries are shown in table 1, and the designed geometries are as shown in figure 2.

Table 1: Dimensional Specifications of the Designed Circular, Rectangular and Square MPAs

Frequency (GHz)	Rectangular patch Length (mm)	Rectangular Patch Width (mm)	Square Patch Length (mm)	Circular Patch Radius (mm)
5.3	17.21	12.93	17.21	8.67
7.5	12.16	8.88	12.16	6.41

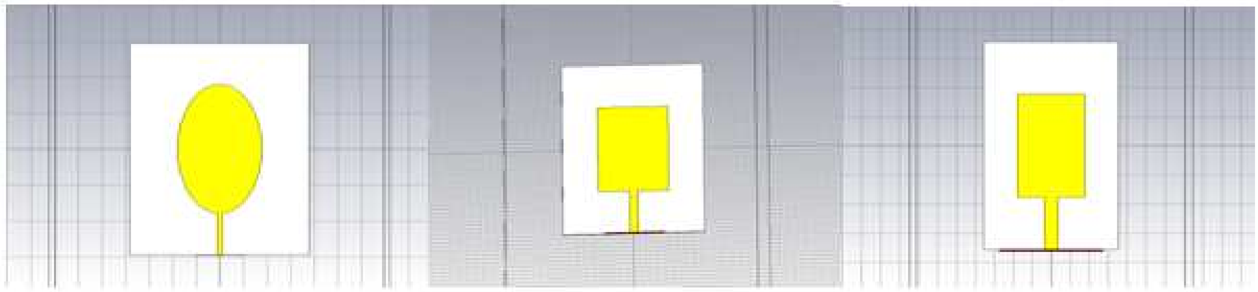
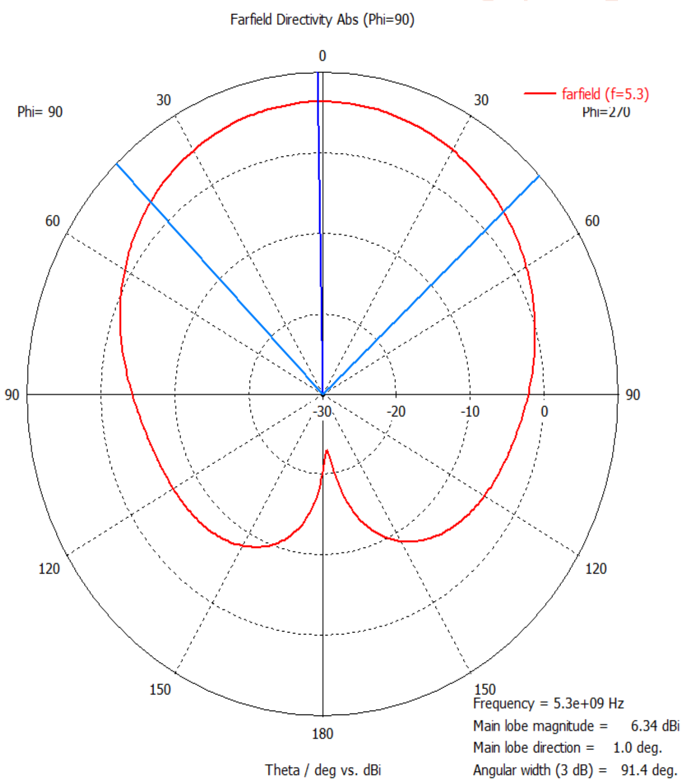


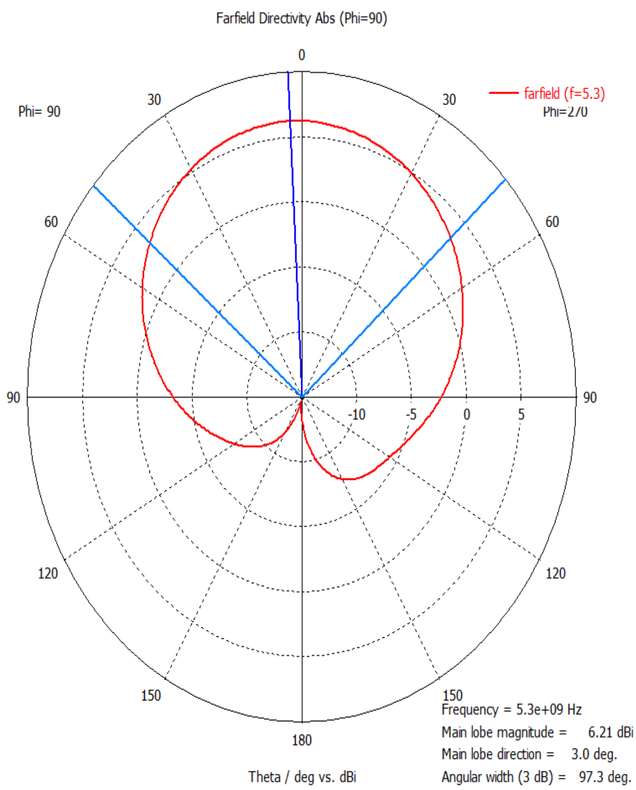
Figure 2: Designed and Simulated Circular, Rectangular and Square MPA Geometries.

IV. Simulation Results

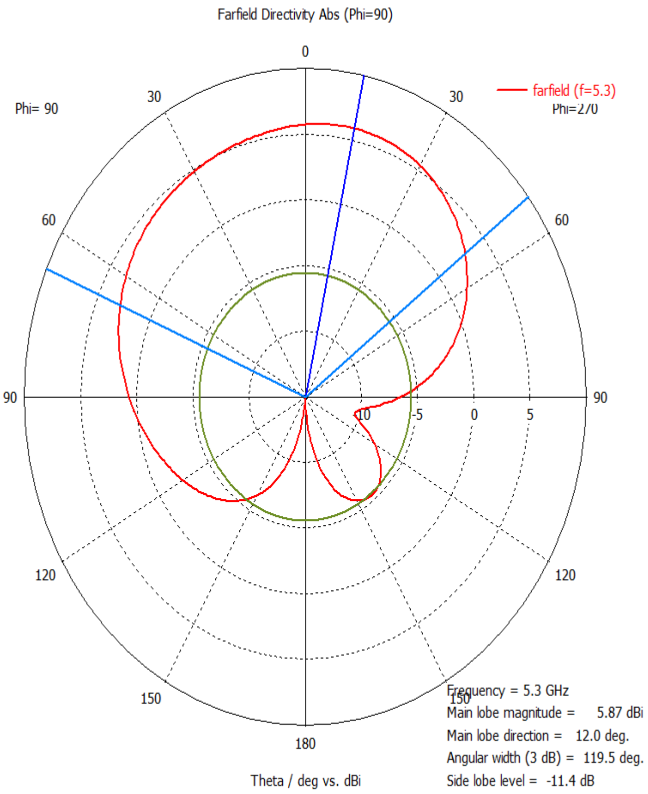
The power radiated by an antenna is the measure of the antenna's strength or power directed in the main lobe [12]. Figure 3a to 3f show the power radiated by the designed and simulated MPAs geometries at 5G network frequencies of 5.3 GHz and 5.7 GHz respectively. The power radiated by these geometries were measured from figures 3a to 3f and presented in table 2.



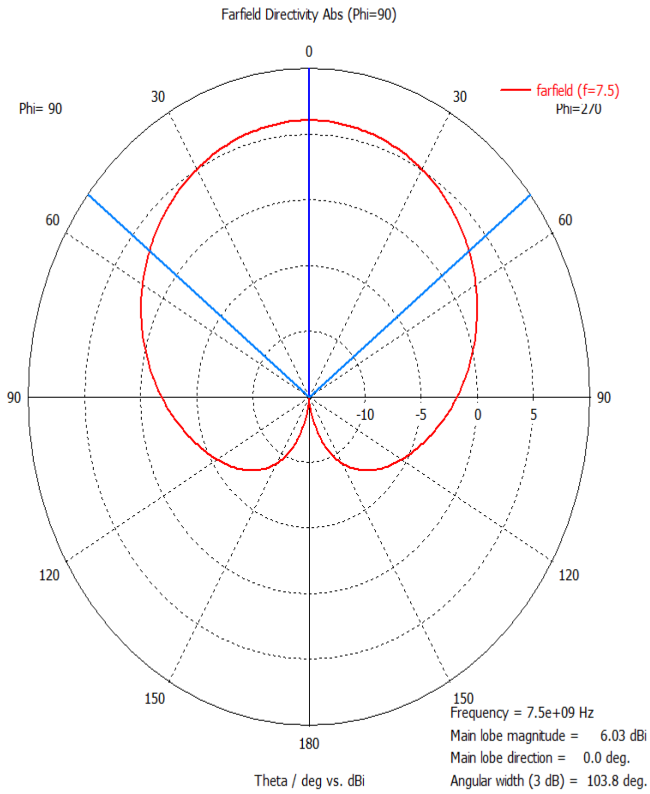
3a



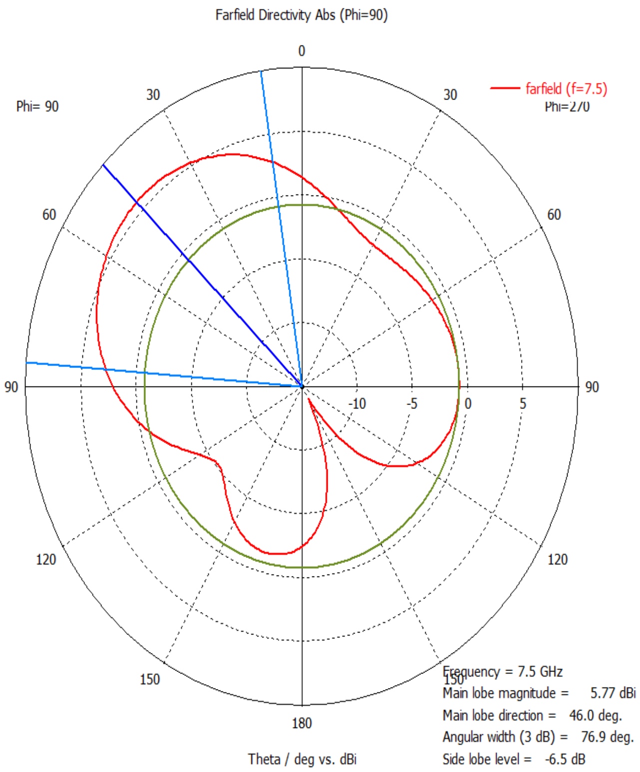
3b



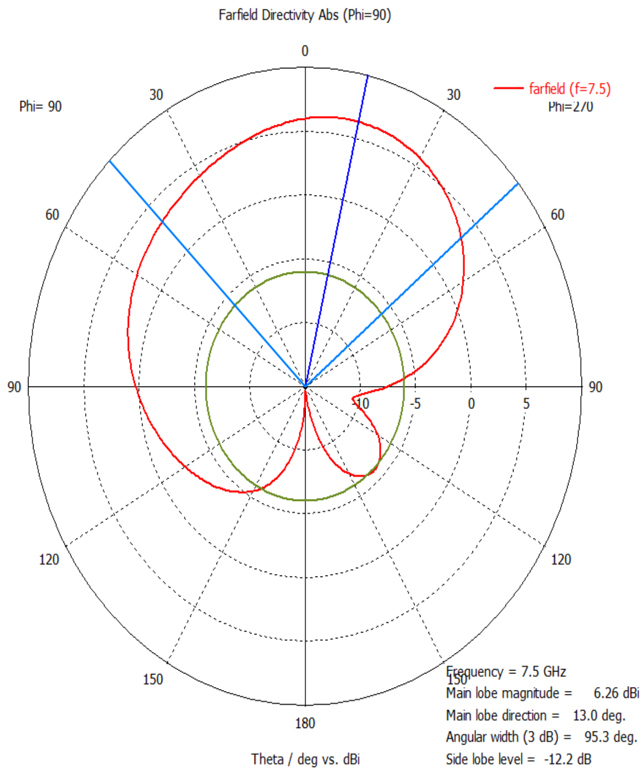
3c



3d



3e



3f

Figure 3: Radiation Patterns of the designed and simulated MPAs geometries; **(3a)** Circular MPAs at 5.3 GHz **(3b)** Rectangular MPAs at 5.3 GHz **(3c)** Square MPAs at 5.3 GHz **(3d)** Circular MPAs at 7.5 GHz **(3e)** Rectangular MPAs at 7.5 GHz **(3f)** Square MPAs at 7.5 GHz

Table 2: Power radiated by the designed and simulated Circular, Rectangular and Square MPAs

Frequency (GHz)	Power Radiated (W)		
	Circular	Rectangular	Square
5.3	0.071	0.176	0.021
7.5	0.072	0.03	0.041

The antenna gain is similar to antenna directivity in terms of definition. The distinction between these two antenna characteristics is that gain considers both the antenna's efficiency and directivity, therefore the gain of a lossless antenna is equal to its directivity[11].The directivity of an antenna is equal to the ratio of the maximum power density to its average value over a sphere as observed in the far-field of an antenna. The evaluated gain, directivity and efficiency of the designed and simulated MPAs geometries estimated from the power radiated in figures 3a to 3f are shown in table 3.

Table 3: Gain, Directivity and Efficiency of the designed and simulated MPAs

Frequency(GHz)	Gain (dBi)			Directivity (dBi)			Efficiency		
	Cir.	Rect.	Sqr.	Cir.	Rect.	Sqr.	Cir.	Rect.	Sqr.
5.3	2.02	2.64	-1.69	6.34	6.21	5.87	0.32	0.43	-0.29
7.5	2.00	3.12	1.16	6.03	5.77	6.26	0.32	0.54	0.19

V. Discussion

The performance of the designed and simulated MPAs parameters were compared as shown in table 2 and table 3. The results from table 2 showed that the designed and simulated rectangular MPA has the highest radiated power of 0.176 W at 5.3 GHz followed by circular MPA which radiates 0.071 W. Square MPA has the least radiated power of 0.021 W at 5.3 GHz. Meanwhile, circular MPA has the highest radiated power of 0.072 W at 7.5 GHz followed by square MPA with 0.041 W while rectangular MPA has the least radiated power of 0.03 W at 7.5 GHz.

Observations from table 3 show that the designed and simulated rectangular MPA has the highest gains with peak values of 2.64 dBi and 3.12 dBi at 5.3 GHz and 7.5 GHz followed by circular MPA with gain values of 2.02 dBi and 2.0 dBi at 5.3 GHz and 7.5 GHz respectively. Moreover, circular MPA has the highest directivity of 6.34 dBi at 5.3 GHz while square gave the highest directivity of 6.26 dBi at 5.7 GHz. Furthermore, the results also show that the designed and simulated rectangular MPA is the most efficient of the three MPAs geometries with an efficiency of 0.43 and 0.54 at 5.3 GHz and 7.5 GHz followed by circular MPA whose efficiencies are the same at both frequencies.

VI. Conclusion

This work has revealed that MPA geometry has critical influence on its performance parameters particularly radiation pattern, radiated power, gain, directivity and efficiency. Rectangular MPA which gave the overall best performance will be most suitable and compatible for use as MPA in 5G network transceiver devices at the lower and mid frequency band, specifically at 5.3 GHz and 7.5 GHz respectively.

References

[1] Balanis, C.A. (2005) Antenna Theory Analysis and Design. 3rd Edition, John Wiley & Sons, Hoboken. - References - Scientific Research Publishing [Internet]. [cited 2022 Jan 11]. Available from: https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=2078988.

[2] Singh I, Tripathi VS. Micro strip Patch Antenna and its Applications: a Survey. [cited 2022 Jan 11]; Available from: www.ijcta.com.

[3] Islam MT, Shakib MN, Misran N. Broadband E-H Shaped Microstrip Patch Antenna for Wireless Systems. Progress In Electromagnetics Research [Internet]. 2009 [cited 2022 Jan 11]; 98:163–173. Available from: http://www.jpier.org/PIER/pier.php?paper=09082302.

[4] Bharadwaj R. Design of Micro-Strip Patch Antenna Array Using DGS for ISM Band Applications. Global Journal of Research and Review [Internet]. 2017 [cited 2022 Jan 11];4:1–4.Available from: https:// journals .index copernicus.com/ publication /1715 125 /Roopali-Bharadwaj-Design-of-Micro-Strip.

[5] Abbaspour M, Hassani HR. Wideband star-shaped microstrip patch antenna. Progress in Electromagnetics Research Letters. 2008;1:61–68.

[6] Adewumi HK, Adewumi AS, Fajinmi GR, et al. Optimization of microstrip patch antenna's bandwidth using fabricated multiwall carbon nanotubes-Al2O3-ceramic composite substrate. Journal of Physics: Conference Series [Internet]. 2021 [cited 2022 Jan 29]; 2034:012020. Available from: https://iopscience.iop.org/article/10.1088/1742-6596/2 034/1/012020.

[7] Chowdhury MH, Hossain QD, Azad Hossain M, et al. Single feed circularly polarized crescent-cut and extended corner square microstrip antennas for wireless biotelemetry.

International Journal of Electrical and Computer Engineering. 2019; 9:1902–1909.

[8] Memon MI, Paliwal A. Microstrip Patch Antenna Design Calculator. IJERT [Internet]. 2013;2. Available from: www.ijert.org.

[9] Rahman Z, Mynuddin M. Design and Simulation of High Performance Rectangular Microstrip Patch Antenna Using CST Microwave Studio Design and Construction of a Magnetic Levitation System Using Programmable Logic Controller View project Design and Simulation of High Performance Rectangular Microstrip Patch Antenna Using CST Microwave Studio [Internet]. 2020. Available from: www.global sientificjournal.com.

[10] Jain K, Gupta K. Different Substrates Use in Microstrip Patch Antenna-A Survey [Internet]. International Journal of Science and Research (IJSR) ISSN. 2012. Available from: www.ijsr.net.

[11] Matzner H, Levy S. Antenna Gain. 2004.

[12] Radiated Power and Field Strength from UHF ISM Transmitters [Internet]. [cited 2022 Jan 17]. Available from: https ://www. maxim integrated .com/en/design/technical-documents/app-notes/3 /3815.html.