

Numerical Modeling of Planar Electromagnetic Devices at High Frequency Using 3D CAD Programs

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Abstract - This paper represents a short introduction to the high frequency numerical modeling and the software programs used in this scope. Considering the present evolution of the software programs used in order to obtain the devices characteristics at high frequency, a waveguide and a patch antenna will be modelled with two different software in order to compare the results and to determine their main parameters.

Keywords – high frequency modeling, patch antennas, waveguide, S-parameters

1. INTRODUCTION

For the structures studied at high frequency, the use of specialized commercial software programs for large frequency ranges is mandatory. These programs allow the user to determine the parameters of interest for every device used at high frequency.

There are a lot of software programs specialized in HF, [1], [2], but this study is a comparison between two of them, namely HFSS and FEKO.

1.1. General description of the software programs used

HFSS is a software package known worldwide as a reference in the area of field numerical analysis at high frequency. Using this software the user can compute: electromagnetic field problems and, for open boundary problems, radiated near and far field, characteristic port impedances and propagation constants, S-parameters and resonances of a structure [2]. The simulation includes post-processing commands for the detailed analysis of the structure's electromagnetic behavior.

Because this program was one of the first of its kind launched on the market and due to its generality and flexibility, HFSS is one of the most popular programs in industry for HF. All the solutions given by this software are based on the Finite Element Method (FEM) of the considered topology. One of its very useful characteristics is the automatic generation and refinement of the mesh [2], [5].

The other considered software program is FEKO. The multiple techniques available within FEKO make possible the application of this program to a wide range of problems from industry. Typical applications include: antennas, EMC (electromagnetic compatibility), bio electromagnetism, radiofrequency components, circuits, planar structures problems and dispersion problems. At the base of the software programs is the Method of Moments (MoM) hybridized with the following technical solutions: FEM, physical optics (PO), geometrical optics (GO), uniform theory of diffraction (UTD). This hybridization implies that the solving techniques can be applied to different parts of a model in order to optimize the solving time and the results. This program also works with meshes for which the densities are variable and defined by the user [1.]

Both programs can determine the S-parameters, near field, far field, gain, radiation efficiency, Specific absorption rate (SAR) and other parameters characteristic to devices used at high frequency.

The next study will be a comparison between the two software programs previously mentioned regarding the model construction, boundaries and excitations that can be applied, and their obtained results for the study of the same device.

2. MODELING A WAVEGUIDE AT HIGH FREQUENCY

Waveguides function based on the total reflection at the interface between two environments. The guiding process is around a space direction. It is considered that in a waveguide there is a region where the wave is propagating surrounded by a region where the electromagnetic field is not propagating. The planar waveguides are considered to have rectangular core and

are used for transmitting information over a short distance. These waveguides are generally made from semiconductors with specific technologies and their refractive index depends on the wavelength λ . They are used for information transmission for the λ for which the losses are minimal [7].

The structure modeled for this study is a rectangular waveguide with the following dimensions:

- KU-BAND: length 15.8 mm, width 12 mm and height 7.9 mm;
- X-BAND: length 22.9 mm, width 12 mm and height 10.2 mm.

In the following section the construction of this structure with both HFSS and FEKO will be presented.

2.1. Waveguide model in HFSS

The first step in the construction of the waveguide is constructing the geometry as it can be observed in figure 1. The interior of the structure was considered to be air and the structure is considered to be a perfect conductor. The excitations for this structure are two waveguide ports, one for each end and their polarity. In figure 2 the construction and polarity of the ports can be seen. The final step is defining the frequency range for the study namely between 9.4872 GHz and 20 GHz.

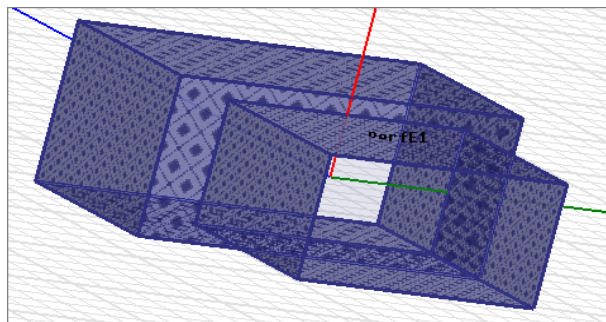
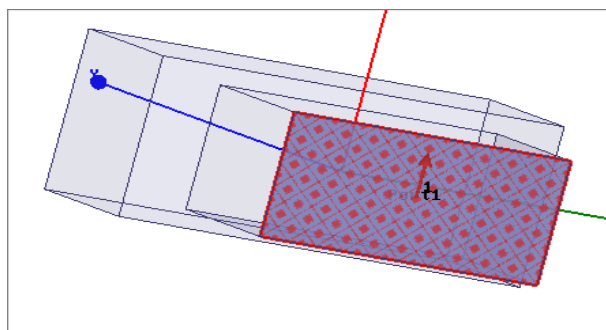
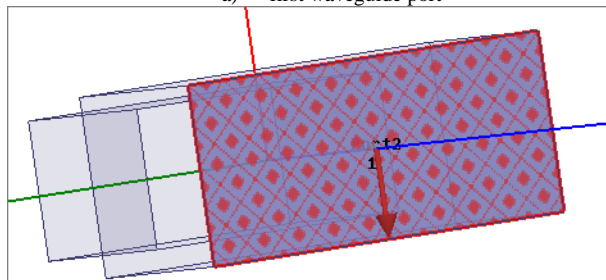


Fig. 1 – Model of the waveguide in HFSS.



a) first waveguide port



b) second waveguide port

Fig. 2 – Setting the waveguide ports in HFSS.

2.2. Waveguide model in FEKO

The next step was the construction of this waveguide in FEKO. The geometry construction is basically the same, but after uniting the two cuboids from which it is constructed, the face between them must be deleted by the user and the structure is considered a perfect conductor by default as it can be seen in figure 3. The next steps are the same namely placing the waveguide ports as in figure 4 and defining the same frequency range.

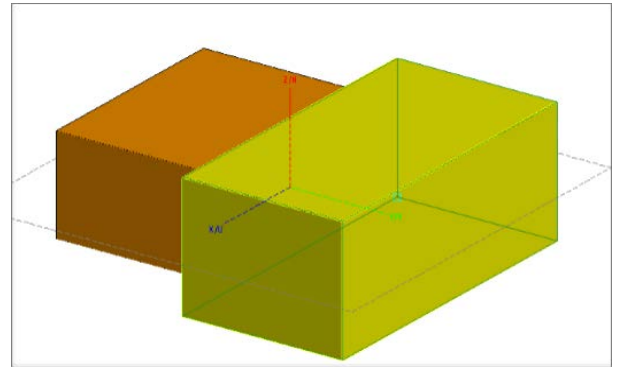
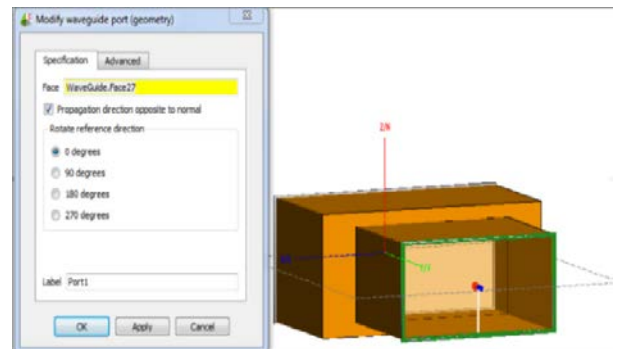
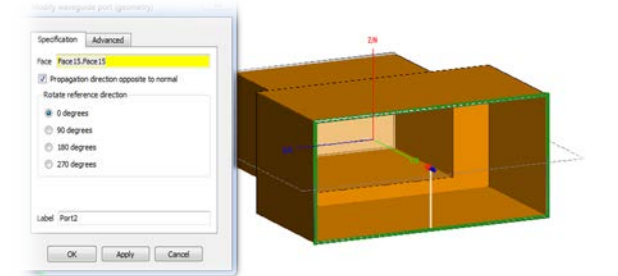


Fig. 3 – Model of the waveguide in FEKO.



a) first waveguide port



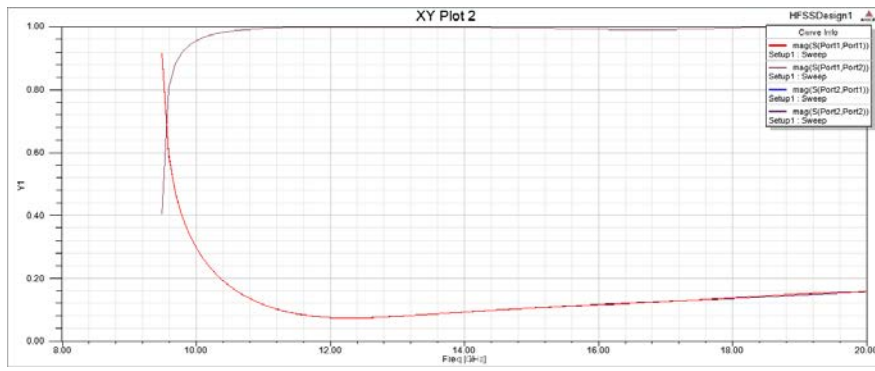
b) second waveguide port

Fig. 4 – Setting the waveguide ports in FEKO.

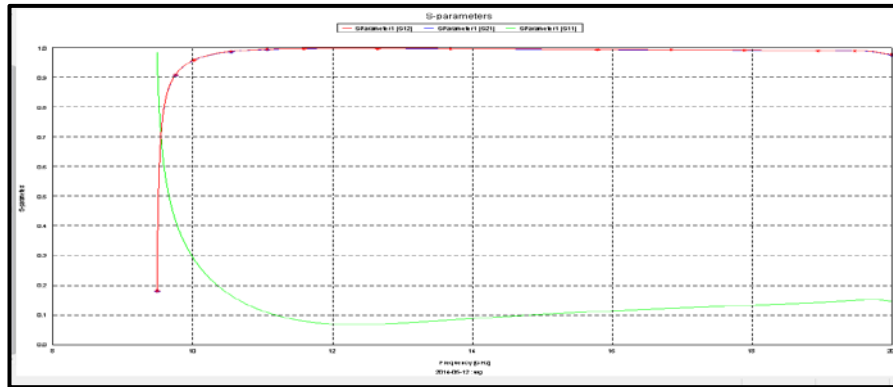
In both programs, the S-parameters for the studied structure were obtained.

The S-parameters describe the electric behavior of the linear electric networks when subjected to electrical signals. A lot of electric properties can be expressed using S-parameters such as gain, losses, VSWR, reflection coefficient and amplification stability, thus determining their value is mandatory for the studied structures.

The results obtained from both software programs for the S-parameters can be observed in figure 5. It can



a) HFSS results



b) FEKO results

Fig. 5 Results obtained from the two considered software programs.

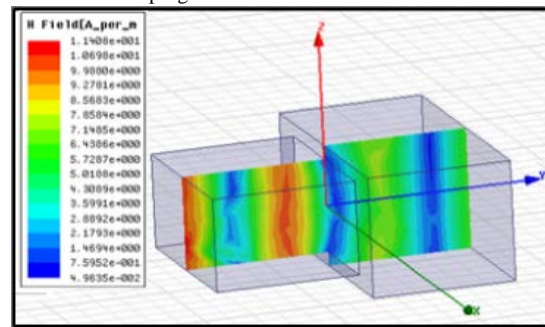
be seen that although there are some differences regarding the geometry construction in the two programs, the results are the same.

Some of the differences noted in the modeling of this geometry with both programs are the fact that the mesh in FEKO must be defined by the user and calculated depending on the wavelength, unlike in HFSS where it is automatically determined by the program, and that the characteristics of the geometry and the materials used are differently specified in these two software programs.

Also, in HFSS the magnetic and electric field could be determine along a section of the waveguide as it can be seen in figure 6.

3. MODELING A COAXIAL CABLE FED PATCH ANTENNA AT HIGH FREQUENCY

The study of patch antennas is of great importance because of their varied field of application, dimensions, weight and performances [3], [4].



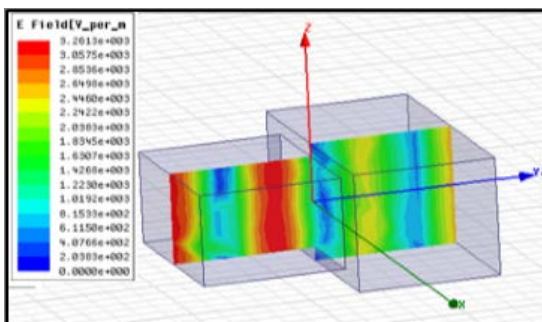
b) Magnetic field

Fig. 6 Field distribution in x=0 plane.

These antennas are used in telemetry, rocket communications, altimeters on board of the aircrafts, air topography, naval communication, automatic guidance for the “smart weapons”, GPS systems and mobile phones among others. In its fundamental form, a patch antenna is made out of a conductor substrate which represents the patch antenna, a dielectric substrate on which the antenna is placed, and a grounded plane placed on the inferior face of the substrate [4], [5], [6].

The patch is radiant and it is generally made out of a conductive material, like copper or gold. The patch can take a lot of shapes: square, rectangular, circular, ellipsoidal or other common shapes.

For a rectangular patch the length of the patch is usually determined based on the wave length, while its thickness is very small. The height of the dielectric substrate is also calculated based on the wavelength and its dielectric constant must have a value between 2.2 and 12 [5].



a) Electric field

All the patch antenna parameters control the antenna properties. The length of the patch controls the resonance frequency, while the width controls the input impedance and radiation. The relative permittivity controls the parasitic fields because it is known that a small value of the permittivity leads to a better radiation and efficiency of the antenna. The height of the substrate also affects the wavelength and it is proportional with it.

There are a lot of possibilities when the feeding methods are considered: inset feed, coaxial cable feed, feed with a quarter wavelength transmission line, aperture feed. For this study the coaxial cable feed was considered and the construction of such an antenna is presented in figure 7.

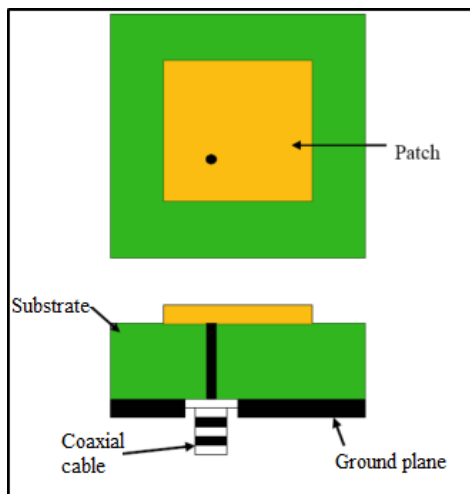


Fig. 7 Coaxial cable feed of the patch antenna.

3.1. Construction and analysis setup for the patch antenna in HFSS

The geometry of the structure is constructed as it can be seen in figure 8, considering as material for the dielectric substrate Rogers RT 5880 from the program's library of materials. For the ground plane and the patch antenna a perfect electric conductor is chosen.

A conductor cylinder presented in figure 9 is passed through the dielectric material representing the coaxial cable between the ground plane and the patch on which a waveguide port is placed.

The analysis is set up in order to determine the far and near field, S parameters, SAR, gain and radiation efficiency. The frequency range considered was between 1 GHz and 3.5 GHz.

3.2. Construction and analysis setup for the patch antenna in FEKO

The construction of the rectangular patch antenna feed with a coaxial cable is different in FEKO. The variables considered as dimensions for its geometry can be previously defined which will help when these parameters are used in many places.

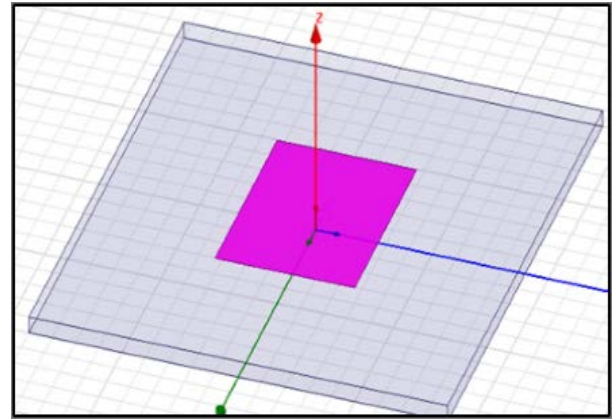


Fig. 8 Geometry construction of the patch antenna in HFSS.

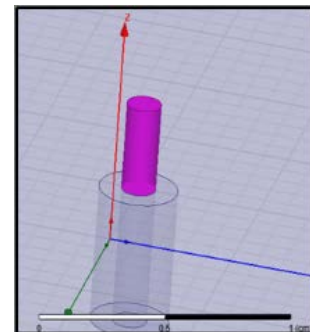


Fig. 9 Construction of the coaxial cable.

This program does not have a material database so each of the structures is initially considered as a perfect electric conductor and the user has to define the materials with their properties. The ground plane will not be separately drawn, so the design is simpler, only the lower face of the dielectric material being changed in a perfect conductor. The patch is separately drawn and all the components have to be united.

In order to place the port, a line is drawn and its position depends on the wavelength. Also, this line has to be between the patch and the ground plane and a line port has to be placed on it. The frequency range is the same as in HFSS and the mesh suggested by the program has to be 4 times smaller in order for the program to run and return viable results.

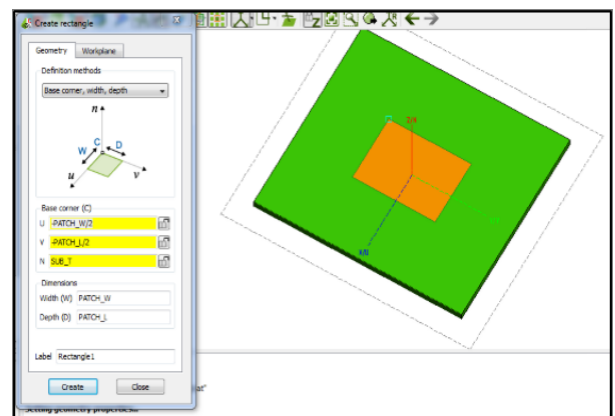


Fig. 10 Geometry construction of the patch antenna in FEKO.

The parameters presented in this study are the S parameters and the results reassemble. The differences are minor and come from differences in the geometrical construction of this patch antenna in the two programs and the mesh constructed for the analysis of these structures. The results are presented in figure 11 for HFSS and FEKO.

information about the method to determine an optimum mesh based on wavelength.

FEKO helps us by simplifying the model, letting the user chose the material for each of the faces of the structure.

Another difference between these two software programs is the type of ports, which differ so the user,

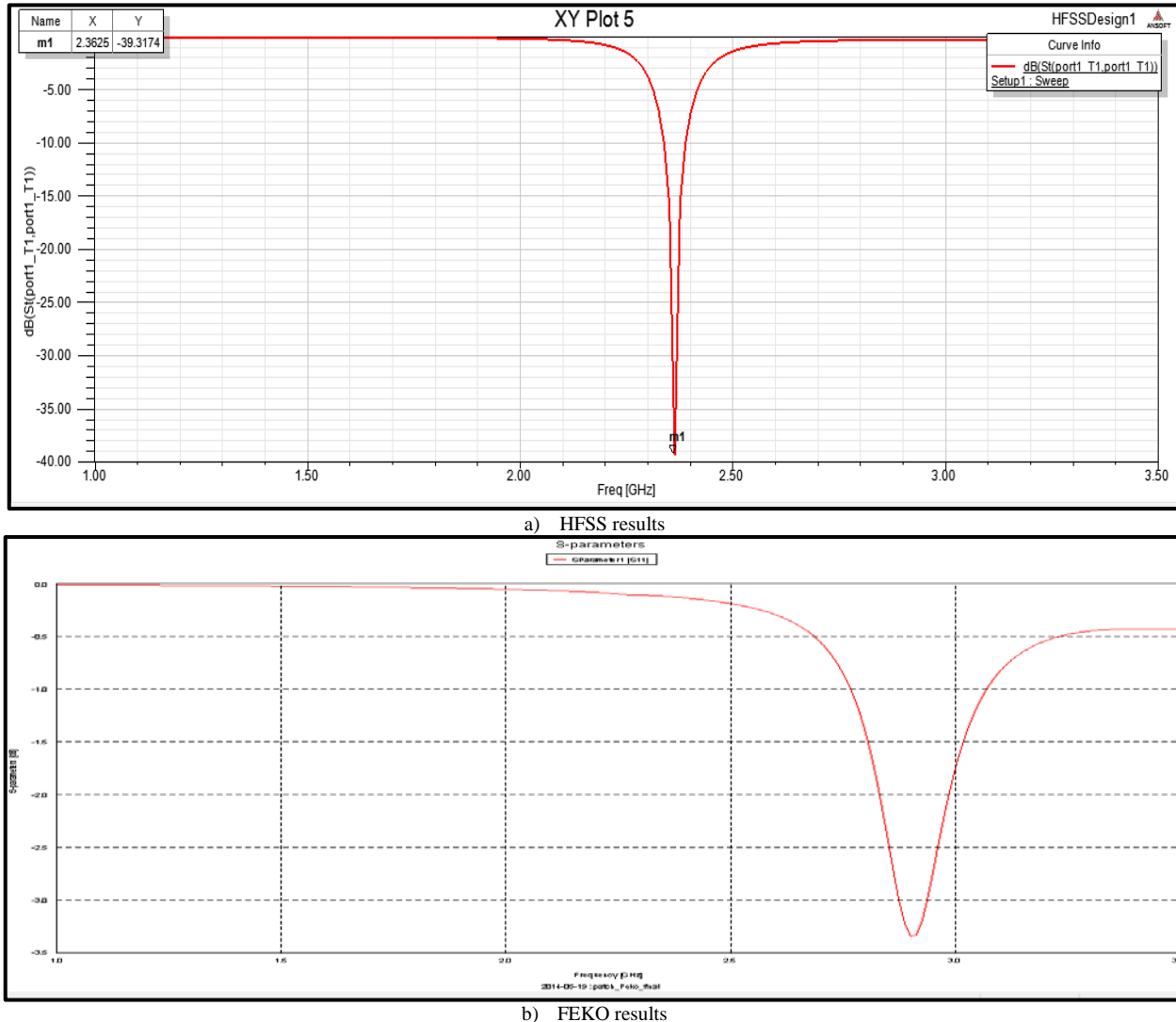


Fig. 11 Results obtained from the two considered software programs for the S parameters of a patch antenna.

4. CONCLUSIONS

After considering the two software programs, HFSS and FEKO, in order to determine the characteristics of different structures, it can be stated that the programs are both efficient in determining the characteristic parameters at high frequency. They are both reliable and are easy to use.

The differences between them can be observe when a geometry is created. HFSS has a large material database which helps the user, while in FEKO the user must define the materials used. Also HFSS creates automatically the mesh for the studied object, which is useful for a beginner, while FEKO lets the user to define the mesh, giving him a suggestion and providing

if he wants to obtain optimum results, must know how to use each and every type of port.

Some differences may appear in the solutions because of the methods on which the programs are based.

Also the user must consider the possibility of combining this programs with other ones in order to achieve better solutions. From this point of view, HFSS has complementary programs made by the same producer and it is more developed than FEKO.

As a general conclusion, even though the programs have a lot of differences, the results given by them for the studied structures are similar. It cannot be said which program is best for modeling, each user choses the one with which he is more familiar.

ACKNOWLEDGMENT

This paper was supported by the Post-Doctoral Programme POSDRU/159/1.5/S/137516, project co-funded from European Social Fund through the Human Resources Sectorial Operational Program 2007-2013.

REFERENCES

1. Hebedean, Claudia, Munteanu, C., „Numerical Modelling of Microstrip Patch Antennas”, Acta Eelectrotehnica , 4 Noiembrie 2010, Cluj-Napoca, Romania, Editura Mediamira Science Publisher, pp. 281-284.
2. Guy A.E., Vasylychenko A., Vasylychenko V., „A Practical Guide to 3D Electromagnetic Software Tools”, Katholieke Universiteit Leuven, Belgium.
3. Wu S.C., Alexopoulos N.G., Fordham O., “Feeding structure contribution to radiation by patch antennas with rectangular boundaries,” IEEE Trans. on Antennas and Propagation, vol. 40, pp. 1245–1249, Oct. 1992.
4. Orban D., Moernaut G.J.K., ”The Basics of Patch Antennas”, www.orbanmicrowave.com.
5. Singh A. P., Kumar R., Dadhwal H.S., “Design of edge fed rectangular microstrip patch antenna for WLAN applications using Ansoft-HFSS”, VSRD-IJEECE, vol 2, 2012, pp. 160-167.
6. Gujral M., Li, J.L.-W., Yuan T., Qiu C-W, “Bandwidth improvement of microstrip antenna array using dummy EBG pattern on feedline”, Progress in Electromagnetics Research, vol 127, 2012, pp. 79-92.
7. Sophocles J. Orfanidis, “Electromagnetic Waves and Antennas: Waveguides”, Department of Electrical and Computer Engineering, Rutgers University.
8. D. Iudean, R. Munteanu jr., V. Zaharia, M. Dobra „Reliability Indicators Analysis for the Cam Box Module of Industrial Knitting Machines”, 49th International Universities’ Power Engineering Conference - UPEC2014, September 2nd to September 5th 2014, Cluj-Napoca, Romania, part number: CFP14569-CDR, ISBN: 978-1-4799-6556-4 INSPEC Accession Number: 14697813 Conference DOI:10.1109/UPEC.2014.6934833 Publisher:IEEE

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