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Table of Contents

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Advanced Antenna Prototypes for Indoor and Outdoor Wi-Fi Communication

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Abstract. The design and fabrication of an individual patch antenna were realized in order to obtain an efficient and economical antenna replacement to routers, which operate at 2.4 GHz. This rectangular microstrip antenna was corner truncated rectangular due to its bigger gain compared with the rectangular one, because of losses reduction. With this antenna the indoor communication was possible, but it was not enough to supply the outdoor one. In order to provide also the outdoor service, antenna arrays were developed, on the base of the corner truncated rectangular antenna, considering traditional configurations such as, a driven patch antenna gap coupled to four patches along the edges as a first approximation. As second one, a driven patch antenna directly coupled to four patches along the edges was analyzed, and finally, a driven patch antenna was coupled considering both types of coupling. The last case constitutes a novel structure, which showed the biggest gain, but, experimentally, also showed a little displacement of the central frequency. The indoor and outdoor Wi-Fi communication was possible with the last two arrays. Their main limitations are their sizes, but they have competitive costs.

Keywords: Antenna prototypes, indoor and outdoor Wi-Fi communication.

1 Problem Description

The great demand of Wi-Fi networks has led to the constant search of connectivity improvements; among them has appeared the use of antennas to replace to the original routers antennas, in order to increase substantially the performance, the coverage and the data rate [1].

The gain is another characteristic to improve. The original antennas of low cost routers, provide gains from 1.5 up to 2 dBi, in special cases. In fact, in order toincrease the coverage some manufacturers of routers sell replacement antennas of high gain [2], for indoors and outdoors [3-4].

The aim of this work is to provide alternatives of replacement patch antenna. It is proposed the design and fabrication of an individual and antenna arrays for 2.4 GHz. The direct coupled arrays have provided a major robustness of the signal for indoor and outdoor communication and with lower cost compared to commercial alternatives.

2 Introduction

At the present time, there are several types of printed antennas in the wireless communications. The most common today is the microstrip or patch antenna, which is fabricated by recording the element pattern of the antenna in a metal piece, commonly cooper, connected to a dielectric substrate with a continuous metal layer connected along the opposed side of the substrate, which forms a ground plane. This kind of antennas is relatively inexpensive.

An arrangement patch provides much more than a simple patch gain for a small additional cost, and a bigger broadband.

In this work, we presented the design and fabrication of prototypes of individual and antenna arrays for 2.4 GHz. The tests for sending-receiving signals are realized in order to know their performance

3 Individual antenna prototype

The patch width is calculated using [5-7]:

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

where: c is the constant speed of light in vacuum, ε_r is thedielectric constant substrate, f_0 is the operating frequency.

The patch length is given by: $L = L_{eff} - 2\Delta L$ Where L_{eff} is the effective length and $2\Delta L$ represents the two increments in the length, which are generated by the fringing fields, make electrical length lightly larger than the physical length of the patch. The length and width of ground plane are [5]:

$$L_g = 6h + L \text{ and } W_g = 6h + W , \tag{2}$$

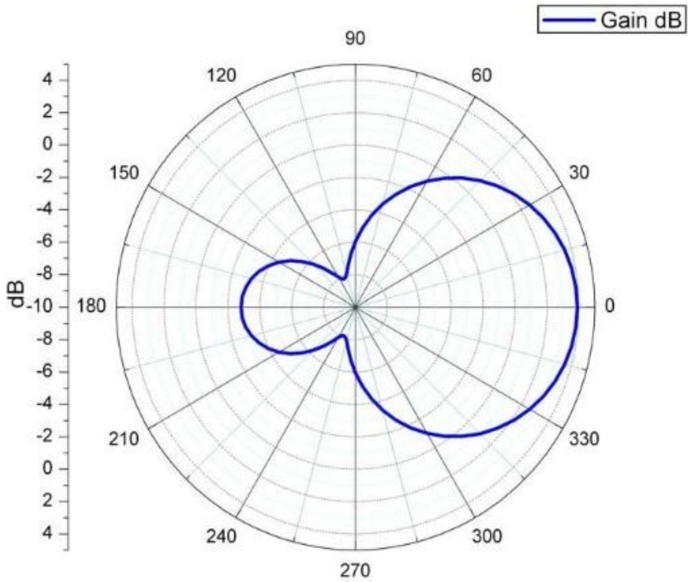

Fig. 1. Beam width of patch antenna.

Using 2.4 GHz as the operation frequency, and 1.6 mm asthe width of FR-4 PCBs plates, the values of W and *L*, are 3.95 cm and 3.08 cm, respectively. The feed point location since the antenna center is (-0.005 m, 0).

For simulation of the antenna performance, we use FEKO, which offers several tools for the patch antenna simulation, and has very friendly environments.

3.1 Modified Antenna

Rectangular patch antenna designs were realizedconsidering some variations, such as cuts and grooves.The rectangular geometry with cuts showed biggest simulated gain and was used as individual prototype.

The gain ratio between the rectangular and rectangular with cuts is 0.78 dB. The cuts depth has 1/8 of group wavelength. The polarization is linear.

The simulations results show a gain from 3.91 up to 4.04 dB for the frequency range from 2.4 up to 2.45 GHz; anda beam width of approximately 90 degrees (Figure 1).

The peak of the electric field was located at 2.41 GHz.The simulated results fit the design requirements. Theimpedance of the antenna considering a 50 Ω load at 2.41 GHz was of 60.51 Ω.

3.2 Individual Antenna Prototype

The fabrication of the individual prototype (figure 2a)was realized on PCBs templates. Coaxial cable of 50 ohms was used for feeding. The final prototype includes a female BNC connector because of its compatibility withthe laboratory equipment.

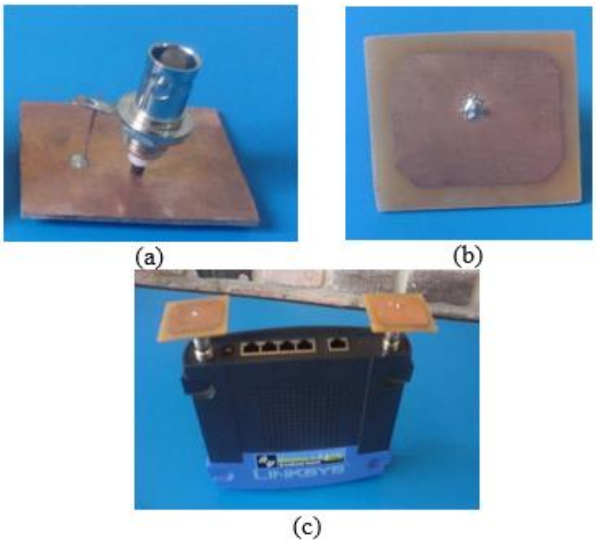

Fig. 2. (a) Individual patch antenna prototype.Frontal view. (b) Back view. (c) Router antenas replacement.

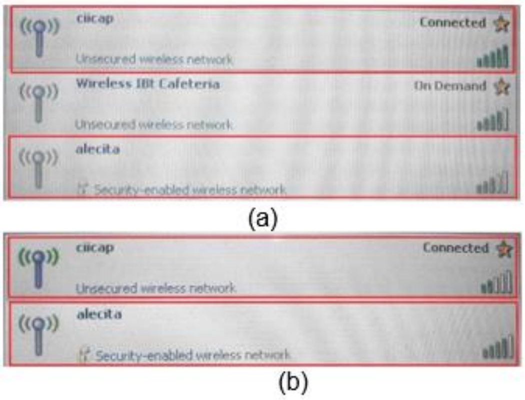

Fig. 3. The received power (a) outside and (b) insideof the CIICAp building.

3.3 Results

The transmission-reception testing was realized inside and outside of CIICAp building. The testing was realized by using a signal generator and a spectrum analyzer, with antenna prototypes coupled by means of coaxial cables. The distance between the antennas was of 6 cm. The peak frequency corresponded to the range from 2,4 to 2,45 GHz, as it was expected.

A comparison with a commercial antenna performance was also realized using two Wi-Fi similar routers. In one of them ("alesita"), we replaced its antennas with our

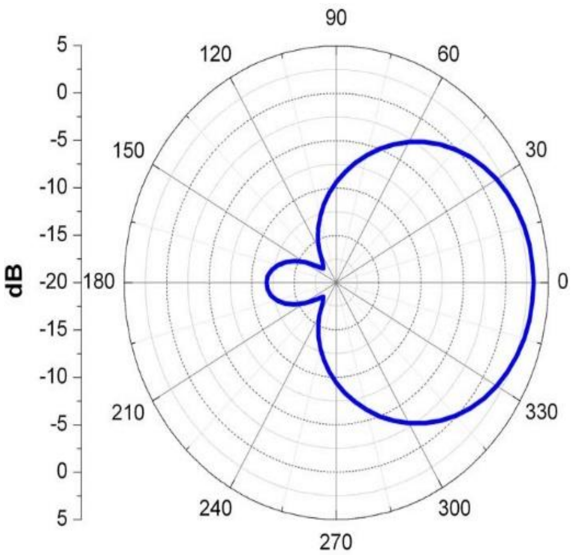

Fig. 4. Gain of the gap-coupled antenna array.

prototypes (figure 2b), while the other one remains with its original antennas ("ciicap"). Figure 3 shows the received power inside and outside of the CIICAp building, using a laptop as reference. As can be seen, outside the CIICAp building, the transmission/reception is better using "ciicap", but inside, the signal is stronger with "alecita". The individual prototype achieves the objective only for indoors.

4 Antenna Arrays Prototypes

4.1 Gap-coupled Array

In order to improve the reception outside of the building, we proposed at first the design of gap-coupled arrays. For the case of a spacing equal to approx. 8 mm, the gain was approximately 3.2 dB (figure 4).

The back radiation is fewer, in this case (-12 dB), than forthe individual antenna (-3dB), but this characteristic is notenough to provide a better response.

The transmission-reception testing was realized inside and outside of CIICAp building.

4.2 Direct-coupled Array

For the case of the antenna array connected by microstrip lines, the length of the microstrip lines corresponds to $\lambda g/8$, that is, 8 mm and a width of 2 mm. The impedance of the microstrip, obtained from tables [6] is approximately 60 Ω. The maximum gain is 4.4 dB (figure 5), lightly bigger than the individual prototype. The directivity increased from 3.44, for the case of individual antenna, to 4.47 for the array. The beam

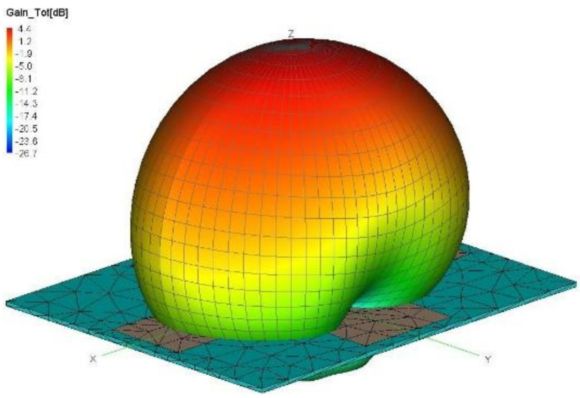

Fig. 5. Gain of the direct coupled antenna array.

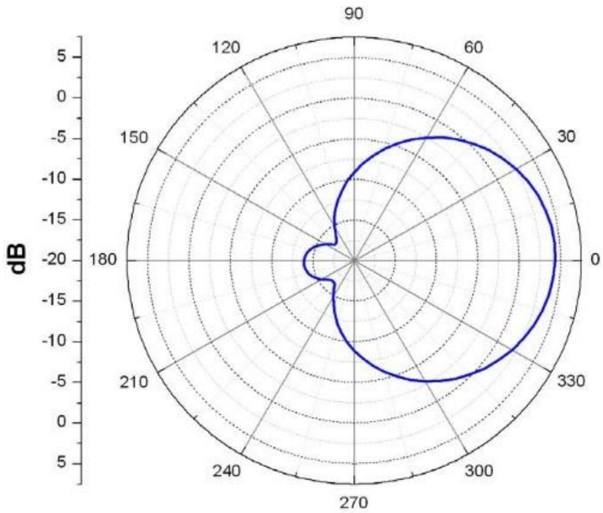

Fig. 6. Beamwidth of the direct-coupled antenna array.

width is similar to the other cases (figure 6). The corresponding prototype is shown in figure 7.

It must be mention that the simulated gain, considering arranges of rectangular with small cuts shape of the antenna components was of 5 dB, lightly bigger than for the case of the rectangular ones, but for simplicity only the rectangular case was fabricated.

The simulated electric field showed a peak in 2.44 GHz. experimentally, the frequency range, where there is a good response, is from 2.445 up to 2.65 GHz. The more representative measurements of the received signal, using a laptop, are shown in figure 8. As can be seen, with the direct coupled antenna array shows a very good response not only inside, but also an acceptable robustness outside of the CIICAp building, which was the aim of this design.We also compared the performance of the router with our antennas, against its performance considering its original antennas, see figure 9.

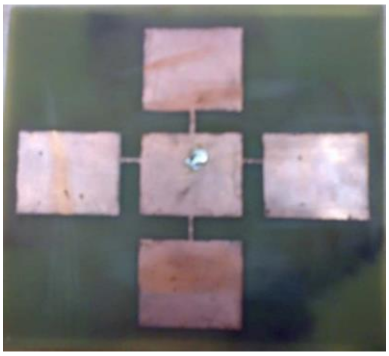

Fig. 7. Prototype of direct coupled antenna array.

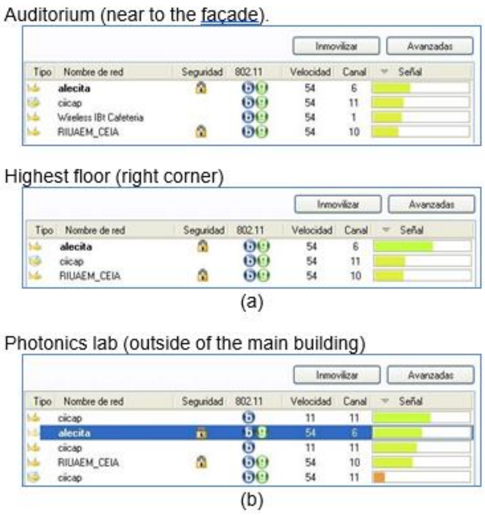

Fig. 8. The received power (a) outside and (b) insideof the CIICAp building using antenna arrays.

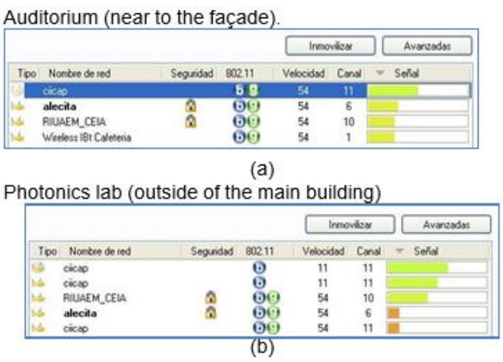

Fig. 9. Received power (a) outside and (b) inside ofthe CIICAp building, considering to the router with itsoriginal antennas.

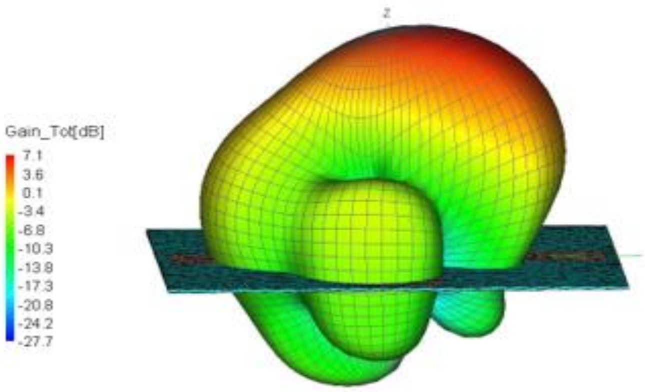

Fig. 10. Gain of mixed-coupled array.

From figures 9 and 10, it can be noted that the router with the antenna prototypes has better reception insideand outside of the building, compared with its performance using its commercial integrated antennas.

4.3 Mixed-coupled Array

Even though the last antenna array made possible to reachour initial objectives, we continue reviewing other configurations based on rectangular patch antennas. Anew proposal was realized considering a mixed-coupled array with a separation of $\lambda g/4$, combining gap and direct coupled antennas. The microstrip used to the direct coupling has a width of 1.45mm. The simulated gain was of 7.01 dB at 2.3 GHz and of 6.435 dB for 2.4 GHz (figures 10). The directivity and the prototype are shown in figures 11 and 12, respectively. The experimental results are satisfactory, but we need to improve the radiation pattern.

It is necessary to note that the gain value corresponds to the direct addition of the individual and the four direct- coupled array gains. But, this result cannot be generalized without to make more proofs.

5 Economic Profit

In this work, without considering the costs of the equipment, the devoted time, and the profit margin, the fabrication net cost of two individual antenna prototypes is approximately of $150 Mexican pesos, considering alsoan ABS cover. This cost is very competitive with the commercial antennas of similar performance. In the case of the antenna array the cost would be substantially increase due to the ABS cover. As it is known, the prices can be drastically reduced if a great scale fabrication is considered. In the case of the antenna arranges, the prices would be lightly increased, specially, due to the cover costs.

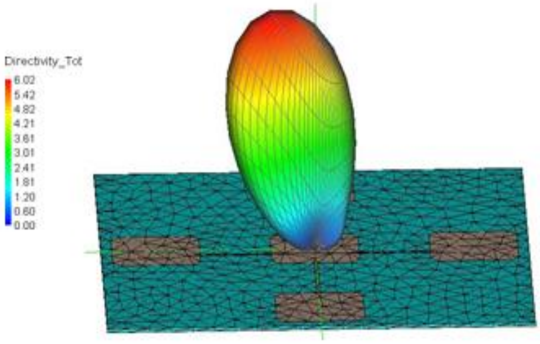

Fig. 11. Directivity of mixed-coupled array.

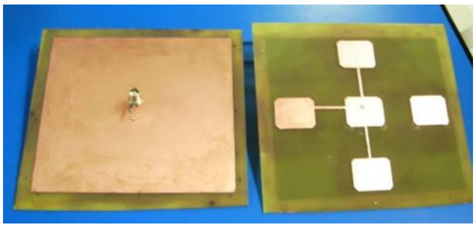

Fig. 12. Prototype of the mixed-coupled array with aseparation of □$_g$/4.

6 Conclusions

The best response for the two cases (individual and antenna arrays) was obtained only using cuts, with approx. 8 mm deep length. For the antenna array, the length of the microstrip lines also corresponds to this value.

The receiving/sending tests showed lightly differences to the simulation results, considering to the corresponding loads. The possible sources of these deviations can be: the feed point has small dimensions in the prototype as well as the feed line. On the other hand, the coupling and the propagation medium also produce additional losses.

The prototype of individual patch antenna shows a good performance for indoor Wi-Fi communications, also in presence of obstacles like walls and in absence of line of sight, whereas the antenna array coupled by microstrip lines shows a better outdoor performance.

The fabrication of the individual prototypes has relatively a very low cost, which makes their use feasible for commercial applications.

For commercial purposes, in the case of direct coupled arrays, the analysis of other substrate materials in order to reduce the sizes must be realized.

The mixed coupling had the biggest gain, but the radiation pattern needs to be improved. Also, it is necessary to obtain more data in order to generalize the obtained result about its gain value.

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Diffraction Effect in a Pulse Propagation

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Abstract. In this work, we present the simulation of propagation of a pulse and the effect of distanceattenuation in the pulse, based on MATLAB. Specifically present the results in the propagation of a Gaussian pulse and its effect on the diffraction spread in the different distances, the pulse corresponding to a HeNe laser. The results show the effect of diffraction on the propagation of the pulse; this informationis useful for example for teaching purposes.

Keywords: Diffraction effect, propagation, pulse.

1 Introduction

Some problems in optical communications are the losses of pulse energy, and that limit the propagation distance. The mechanisms for loss of greater importance that affect the pulsed electromagnetic propagation are: scattering, absorption, diffusion and diffraction, which show different behaviors depending on the intensity of the pulse.

The beam propagation method is a numerical way of determining the fields inside a waveguide. With this method, the mode profile of an unusual waveguides such as couplers can be determined with ease. The dynamic mode profile can be accurately estimated as the wave propagates through the wave guide [2]. The theory is based on a special class of solutions of the Maxwell's equation for beam of electro- magnetic radiation that is reasonably well collimated and having relatively small dimensions, measured in wavelengths, transverse to the axis of propagation.

The solution of the wave equation, in a cylindrical coordinate system is obtained from Helmholtz wave equation:

$$(\nabla^2 + k^2)\Psi = 0. \tag{1}$$

In this equation we assumed that the beam has well defined direction of propagation and some transverse variation. The distribution of the intensity of the electric field at a given distance$z$ along the axis of propagation and at a given perpendicular distance r from the axis.

The parameter w_0 denotes as the beam radius at z=0, which is called *the beam waist radius*, andthe variable w is called the beam radius:

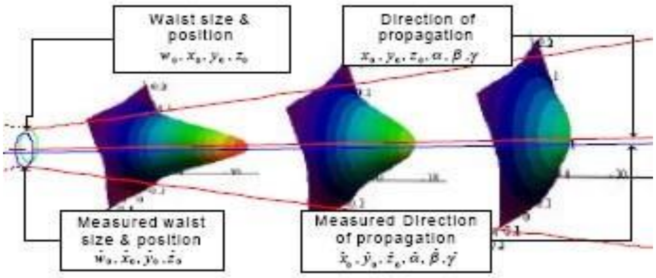

Fig. 1. Propagation scheme.

$$w(z) = w_0\sqrt{1 + (\lambda z/\pi w_0)^2}. \tag{2}$$

Based in the last two equations, we canconclude that the frequency, the beam waist andthe coordinates of the beam waist with its orientation (beam axis direction) are the complete set of the parameters to define Gaussian beam.

To align the HIFI receivers with the antenna beam we need to measure the receiver Gaussianbeams via obtaining their parameters as above with a high degree of accuracy. The proposed measuring technique for the Beam MeasurementRange is to perform a set of power measurements in several parallel cross sections along the direction of beam propagation.

2 Beam Propagation

The beam propagation method essentially decomposes a mode into a superposition of plane waves, each traveling in a different direction. These individual plane waves are propagated through a finite predetermined distance through the wave guide until the point where the field needs to be determined has arrived.

At this point, all the individual plane waves are numerically added in order to get back the spatial mode.

3 Experimental Results

In the following pictures we can appreciate the diffraction effect in a propagation pulse.

In Fig. 1 we show the original pulse.

In Fig. 2, in the next five subpictures the pulse has been propagate a distance of 1000 mm each one. In the seventh subpicture the propagation distance is 8000 mm, meanwhile the last subpicture it is 20000 mm.

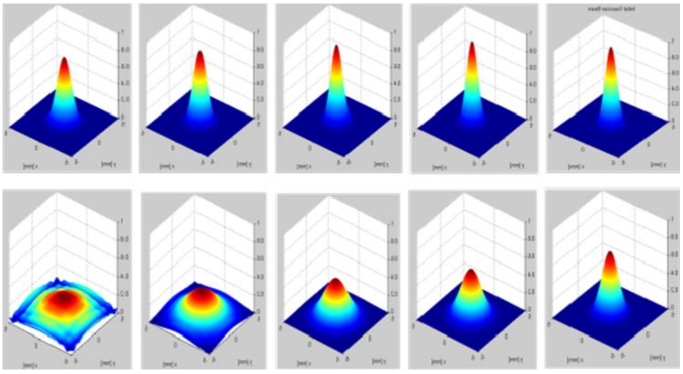

Fig. 2. Propagation with difraction.

4 Conclusions

We successfully used MATLAB for modeling the scalar Gaussian beam. The simulation program was employed for:

- optimization of the measurement procedures, the raw data reduction and investigation of the measurement error components.
- with the optimized procedures and data handling the simulation was used to evaluate ultimate performance of the proposed system and for the measurement error analysis

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Study for the Economical Factibility in the Implementation of the Renewable Energy Technologies for the Electrification of the Rural Community of Media Luna in Salamanca, Gto.

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Abstract. The present work aims at studying the economical factibility of the electrification of the rural community of Media Luna in Salamanca Guanajuato by means of eitherextension of the distribution electrical networkor renewable energy such as photovoltaic or wind power. The study is accomplished by carrying out an accounting of the potential of these energies in the rural community; thisstudy should be used for the electrificationplanning of the rest of the communities.

Keywords: Economical factibility, renewable energy, rural community.

1 Introduction

Currently there exist some rural communities in the City of Salamanca, Guanajuato which lack of the electricity commodity; hence the present work aims at fostering the development of more efficient technology for generation and use of energy as well as strengthening the technological development in the field of renewable energies.

It is worth highlighting that the outcomes can be applied to another rural communities and municipalities having similar features as the one regarded herein, such as socio-economical structure, size, distribution and meteorological conditions.

On account of the research development nature, several studies to evaluate the economic impact that may have the installation of new medium-tension electric grid on costs are carried out. Besides, these studies imply the posts arrangement, wiring and accessories. With the study it will be seen that the CFE negotiation costs can be avoided in contrast to the installation of renewable energy systems.

It is well known that in order to have a general perspective, in the long term, of a project it is necessary to carry out a financial analysis which allows to assess parameters as initial investment and net present value over a certain period of time (for this particular case the time was 20 years). In so doing, the analysis must allow for maintenance costs, overhauling costs and useful life. As well, in order to know if the project is worth in a time- discount calculation, the analysis must take into account a

Fig. 1. Top sight of Media Luna

Minimum Attractive Rate of Return (MARR) which considers the annual inflation rate of the country where the study is carried out. In this particular case, the inflation rate was 3.92% for 2006, and the MARR was 5 %. Finally, however, in order that the most feasible solution can be implemented, socio- economical factors are considered, too.

It is worthwhile stressing that the main beneficiaries of this study are the rural community inhabitants, one of the fundamental aspects to be reviewed is the renewable energy potential in the rural zone, which may be used as base for the electrification planning of the rest of the rural communities.

2 Methodology

The community of Medial Luna is located at the north part of Salamanca bordering with the cities of San Miguel Allende and Juventino Rosas, at 25 kilometers roughly from the urban zone of Salamanca, that is a time travel of 1:40 hours, the number of houses is 10 and the total number of inhabitants is 60.

2.1 Extension of the Distribution Electric Grid

The closest community to Media Luna with electric service is the Joyita de Villafaña; a bi-phase grid line extends 1.5 km from a school located therein, nearby to Media Luna at the northeast side.

The economical proposal delivered by the CFE Company for extending the distribution electric grid up to 1.5 km was $348,422.00. It included the annual consumption costs for thewhole community ($3,835.24) as well as the maintenance costs. Then all these figures are brought to the present value by considering a period of 20 years, which comes to be $535,011.25.

Table 1 shows the value of the initial investment and the net present value over a period of 20 years for extending the electric grid line.

Table 1. Economic effects of photovoltaic system.

Inversión Inicial	$ 398,422.00
VPN 20 años	$ 535,011.25

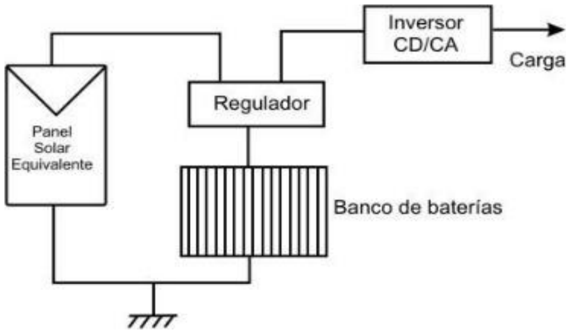

Fig. 2. Main Elements of the Photovoltaic System.

Table 2.

Inversión Inicial	$ 1'421,429.50
VPN 20 años	$ 1'671,906.49

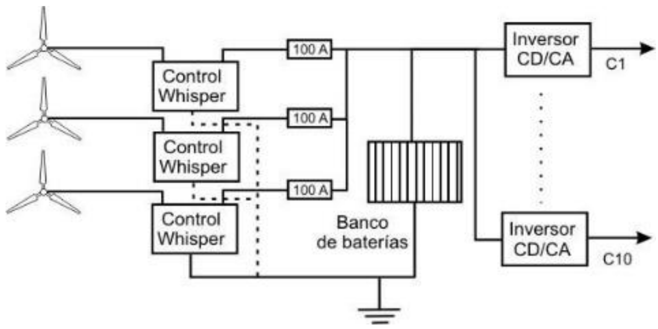

Fig. 3. Wind Energy System Main Elements.

2.2 Photovoltaic Energy

The sizing of the photovoltaic system for eachhouse was carried out by considering a solar irradiance of 4.4 kWh/m^2-day. The mainelements of the system are shown in Figure 2.

The total cost of the photovoltaic systems for 10 houses was $ 1'421,429.50, and calculating by means of the life cycle analysis of the components and maintenance, the annual costs are yielded over a period of 20 years in accordance to the net present value.

Table 2 shows the values for the initial investment and the net present value at 20 years for the whole photovoltaic system.

Table 3. Economic effects of wind energy system

Initial investment	$ 735,386.22
VPN 20 years	$1'048,260.27

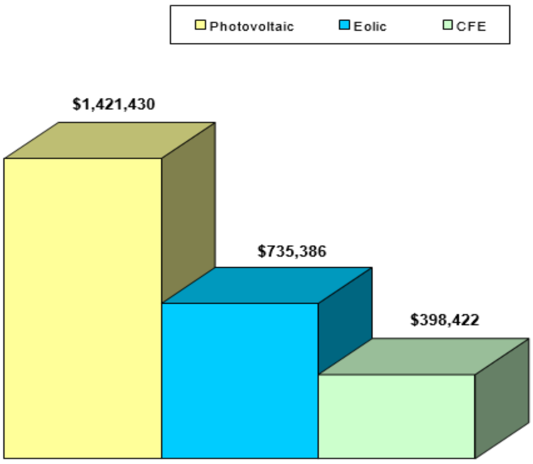

Fig. 4. Initial Investment Figures.

2.3 Wind Energy

As to the wind energy system, an annual windspeed average of 5 m/s was considered, so the whole system for 10 houses is shown in Figure 3.

The total initial investment for the wind energysystem came out to be $ $ 735,386.22. In order to assess the net present value of the project over the period of 20 years, the annualmaintenance costs and the life cycle of the components were included.

Table 3 shows the values for the initial investment and the net present value at 20 years for the wind energy system.

3 Obtained Results

The results yielded by the financial analysis tofind the more feasible solution are shown in Table 1, 2 and 3, with such values the studyof economical factibility is carried out then.

3.1 Initial investment

The minor initial investment is represented by the proposal of extending the distribution grid line by the CFE. The difference between projects is, on the one hand, 1 million pesosin comparison with the photovoltaic systemand, on the other hand, 350 thousand

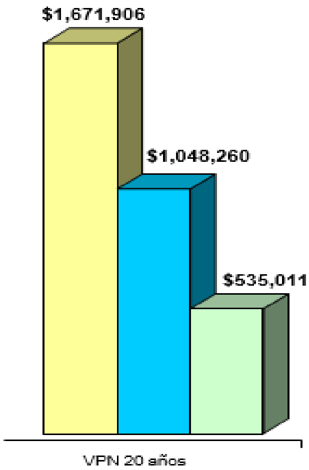

Fig. 5 NPV over 20 years.

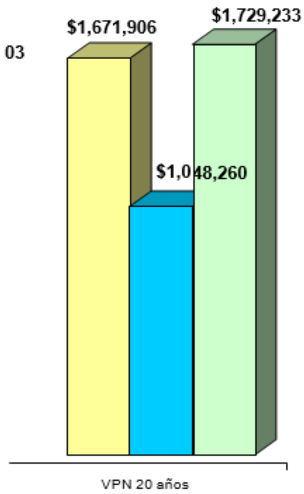

Fig. 6. NPV over 20 years by considering an electricgrid line of 6.5 km long.

if compared with the wind energy system,hence, from the economical point of view, the best option is to extend the electric grid in comparison with the renewable energies, this is two or four times the cost of the initial investment to extend the electric grid line. Figure 4 shows the economical difference among the possible alternatives.

3.2 Net Present Value over 20 years

The net present value points out the value ofthe money at present by discounting all the future outgoings at an appropriate rate of interest, i. e. it resolves the equivalence in thezero time of the future cash-flows originated by a system.

For this particular case where the assessmentis carried out on a cost basis, the system showing the minor NPV will be the more economical feasible. Comparison of the alternatives is shown in Figure 5.

Clearly the results shown in Figure 5 points out that the CFE has the smallest NPV; the reason is that the costs generated by the consumption of energy are smaller than the costs presented by the renewable energies in maintenance and replacement of parts through the lifetime of the system. Thus, according to the NPV analysis, the project concerning the extension of the distributiongrid line is more cost-effective than the renewable energies.

3.3 Electric Grid Line Distance Factor

In order to have the same costs in the projects in the NPV, and if the construction cost of the electric grid line was 260,000 pesos, then the grid line would have to be **6.5 km** long, what indicates that to have a gridline equal or longer, the NPV would surpass the current installation costs of the renewable energies (Figure 6).

However if the distance of the electric grid lineis longer than 6.5 km, then the more cost- effective option is the renewable energies.

3.4 Socio-Economical Factor of the Rural Community

Being the extension of the electric grid line the more cost-effective alternative, it is worthwhile mentioning that, from the socio- economical point of view of the rural community, most of the similar rural communities have to cancel the electricservice because of the high costs in the bill. Estimation indicate that the community of Media Luna would have to pay 60 pesos each two months, which is an amount quite considerable for the inhabitants to the point that they opt for calling off the electric service.

This is a factor that is not considered in the renewable energies insofar as, from the very first time the energy is consumed, the user is completely independent of the generation costs, which is a great advantage in the renewable energies what leads to opt for this type of installations.

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