International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I10P215

Volume 69 Issue 10, 118-127, October, 2021
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Implementation of an FM Radio Station to Facilitate Remote Education in the District of Cojata

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Abstract — *INEI affirms that in 2020 6.7% of the student population of Regular Basic Education (RBE) belonging to rural areas did not access any type of distance education implemented by the Ministerio de Educación (MINEDU) due to social isolation by the National Emergency by the COVID-19. That is why the research work is proposed, which consists of providing coverage with a radio signal in modulated frequency (FM) to the towns that belong to the district of Cojata-Puno and other beneficiaries, to retransmit information related to virtual education denominated "Aprendo en Casa" that is transmitted by web, radio, and television in national channels. In this project, the satellite signal of National Radio of Peru will be used to broadcast the audio programs through the modulated frequency signal, for which studies were first carried out to raise the profile of the project, which consists in obtaining the geographical coordinates and the elevation profile to determine the free space for the propagation of the radio frequency signal and to verify the broad coverage of the signal in the strategic areas, for the location of the places, the different simulations with the support of radio Mobile software, Google Earth and MMANA-GAL, obtaining favorable line-of-sight results with 100% of the first Fresnel zone cleared with respect to the Kantati Ururi community with a reception level of -49.7 dBm which means a high hearing level at the receiver. It is concluded that it is possible to provide a radio signal using FM.*

Keywords *- Radiofrequency; Fresnel zone; rated power; coverage; effective power; impedance; coupling; electric field.*

I. INTRODUCTION

According to Supreme Decree number 044 of the Presidency of the Council of Ministers (PCM) of 2020, in the face of health emergency situations, the government declared a state of national emergency due to the serious circumstances that affect the life of the Nation as a result of COVID-19.[1]This measure prevented all schoolchildren in Regular Basic Education (RBE) from returning to schools, and as an initiative, the Ministerio de Educación implemented strategies of a remote education called "Aprendo en Casa" through the web, radio, and television platforms. [2]

In the report of the Instituto Nacional de Estadística e Informática(INEI), it indicates that in 2020, 94.2% of the population between 6 and 11 years of age enrolled in some grade of primary education received distance classes using some communication technology and Information that included the use of television, radio, and Internet, furthermore, reports that 94.5% of the population between 6 and 11 years old in urban areas and 93.3% in rural areas accessed this type of study.[3]

According to the newspaper La República, in the department of Puno, it is estimated that 35% of primary school students do not have access to any type of communication medium, specifically from the Kantati Ururi community of the Cojata district, Huancané province, such as an alternative, some primary-level schoolchildren chose to walk several kilometers towards the top of the KataniJincho hill located 5 kilometers from the community to receive the signal from a station and listen to the classes offered by the Ministerio de Educación.[4]

In [5], they carried out on educational radio programs and their influence on the behavior of students, so, statistical tests were applied to a population of 357 students from the Manuel Quintana Miranda elementary school in the province of Los Ríos-Ecuador, surveys were applied to 100 participants, obtaining the following result: 47% of school students listen to the radio in the morning, 43% in the afternoon and 10% at night, arriving at the conclusion that educational radio programs are beneficial for students because they are considered a mass communication means with reach to all people without distinction of social position, which affects the quality of life and the behavior of the population.

In [6], they indicate the experiences of social and cultural impacts of Radio in educational communities. The research focused on four educational communities; data collection techniques, observation, interviews, and documentary analysis were applied. As a result, indicate that the implementation of school radio favored the integration of Latin American immigrant students with diverse customs and cultures through the interaction of radio productions with topics of social interest, it also allowed them to recognize their own possibilities of improving themselves and the feeling of being part of a group.

In [7], they indicate experiences with radio programs oriented to education using a methodology of education through entertainment known as education through drama developed with the intervention of a group of educational and community radio stations in Bolivia. One of the greatest experiences of using radio drama to promote citizen values and social inclusion is that it generated spaces for collective reflection, dialogue, and debate with listeners. The radio program "Voces Nuestras" had a successful rating in the broadcast of the 45-episode radio soap opera called "Ciudad espesa" with the content of real stories under three thematic axes: pluralism and human diversity, citizen participation in democracy, and the right to communication and information. The program was broadcast through 28 radio affiliates located mostly in rural areas reaching approximately 200 000 listeners.

The main objective of this research work is to implement an FM radio station to provide coverage area to the towns of the Cojata district, Huancané province; the project profile will be developed using the Google maps application, Google Earth, and for simulation radio mobile software.

The transmission of information through electromagnetic waves occurs through the oscillation of electric and magnetic fields produced by the radio transmitter that, through an antenna, will produce the propagation of electromagnetic waves in space, to then be received by a device that will decode the information sent by the transmitter. In addition, the antenna fulfills an important role that of converting electrical energy into an electromagnetic wave, which according to the type and polarization will be used according to the geographical characteristics of the area, its dimensions depend on the wavelength of the signal of transmitted radio frequency that is related to the operating frequency.

The following research work is structured as follows: in section II, the methodology for transmitting information through radio frequency signals will be presented, in addition to presenting block diagrams, location of geographic coordinates, map reading, and verification of the elevation profile. In section III, the results of the research work will show the parameters of the systems and the simulations with the mobile radio software that will allow verifying the line of sight and their effective performance. In section IV, the discussions of the research work will be presented. Finally, in section V, the conclusions on the research work will be presented, as well as some recommendations and implementation improvements.

II. METHODOLOGY

In this section, the operation of the stages that makes up the system for the transmission of the modulated frequency signal is developed, which consists of the identification of the system, system process, and finally, the result that includes the propagation of a frequency modulated carrier wave. The stages of the system are shown in Figure 1, where the different processes that generate the high-frequency signal carrier are indicated to transmit information.

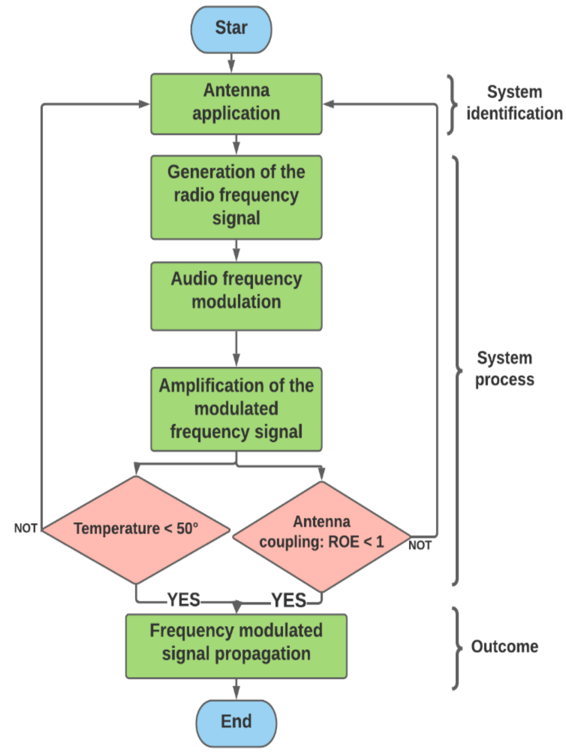

Fig. 1.Flow diagram for the transmission of the modulated frequency signal

A. System identification

For the implementation of the system, an antenna is required that meets the appropriate characteristics to be able to operate in the specific workplace, since the propagation of electromagnetic waves fundamentally depends on this device, for this case, the Yagi antenna of 4 elements for having a good bandwidth for their operation, high gain, vertical polarization, and even radiation directionality, this design is shown in Figure 2.

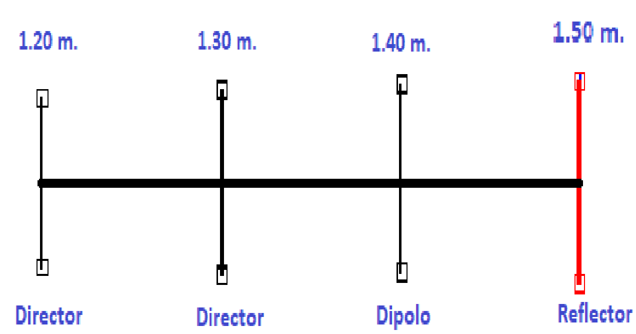

Fig. 2.4-element Yagi antenna

This irradiating element adapts to any frequency to be transmitted, this parameter being important for the implementation according to the frequency assignment by the General Directorate of Telecommunications Authorizations of the Telecommunications of Ministerio de Transportes y Comunicaciónes (MTC), the governing body in charge of the spectrum channeling for the official operation of broadcasting stations.[8].

The characteristics of the antenna are presented in Table I.

TABLE I. CHARACTERISTICS OF THE ANTENNA

Antenna Specifications	
Antenna Type	Yagi
Polarization	vertical
Gain	6.8 dBm
Frequency range	87.5 – 108 MHz
Bandwidth	20 MHz
Impedance	50 ohms
VSWR	< 1.3

The antenna presents a radiation pattern that ensures correct transmission coverage with a signal intensity in a vertical polarization considering that portable frequency-modulated receivers have a telescopic antenna generally in a vertical position, thus facilitating the reception of information without fading during transmissions. The radiation pattern obtained from the MMANA-GAL simulator can be seen in Figure 3.

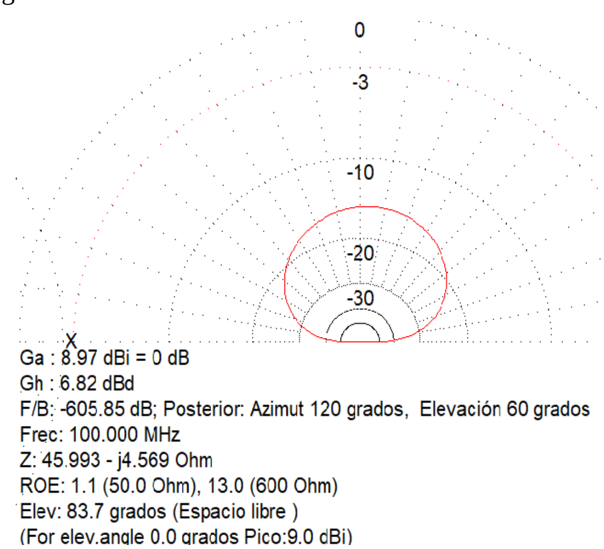

Fig. 3.The radiation pattern of the Yagi Antenna

The location of the antenna is another important factor to have adequate irradiation of the signal, and it will be carried out considering the line of sight with the strategic areas to be covered, for which it is executed using Google Earth according to the geographical coordinates that are shown in the following Table II.

TABLE II. GEOGRAPHICAL COORDINATES

Location	Coordinates	
	Latitude	Longitude
La Rinconada	14°37'15.54"S	69°26'1.25"O
Kantati Ururi	15°12'3.71"S	69° 9'15.85"O

The transmitter will be located in a place called "La Rinconada" because it is an area that has favorable conditions and factors to ensure the transmission of information to the largest possible number of beneficiaries. The topographic profile is observed in the following Figure 4.

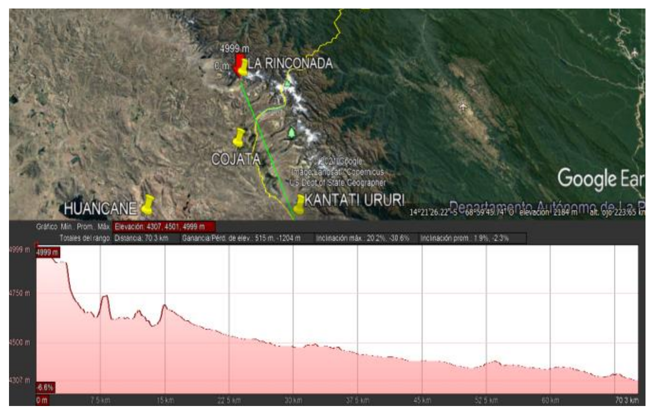

Fig. 4.Topographic profile using Google Earth

To calculate the minimum required size of the tower, an analysis of the line-of-sight profile has been carried out with the different points and to guarantee that it exceeds at least 80% of the first Fresnel zone; using as a reference a height of 30 meters.

During the transmission of electromagnetic waves from the starting point to the receivers, they will suffer increasing losses according to the distance from the receiver; this factor is known as Free Space Loss (FSL) and is calculated by applying the following mathematical formula.[9]

$$FSL\ (dB) = 20Log10(D) + 20Log10\ (f) + 32.4$$

Where:

D (Km): Distance f (MHz): Operating frequency

B. System process

The use of radiofrequency has been increasingly innovative due to its application in different fields such as medicine, meteorology, communications, wireless networks, broadcasting, etc. Its classification corresponds according to the frequencies and wavelengths that are present in the bands of the radioelectric spectrum; in our case, the corresponding band is the Very High Frequency (VHF) comprised between 30 MHz to 300 MHz. Its length is related to the following expression: $\lambda = \frac{c}{f}$ where:

(λ), wavelength (m)
(c), speed of light (m / s)
(f), frequency (Hz)

This indicates that the physical antenna is of a certain length according to the operating frequency.

The modulated frequency signal will be provided by the transmitting equipment, whose characteristics are observed in the following Table III.

TABLE III. TRANSMITTER FEATURES

	TRANSMITTER	PARAMETERS
	Brand	RVR
	Operating Band	88MHz-108MHz
	Power	50-500W
	Power supply	110/220 Vac
TRANSMITTER	Modulation	FM Direct
	Frequency stability	< ± 1%
	Audio Input Level	MPX +9 a -12 dBm, ± 75 KHz
	S/N ratio	70dB
	Distortion	0.05%
	Stereo Separation	45 dB

The main purpose of the transmitter is to encode electrical signals, amplify them, then emit them as electromagnetic waves using the antenna. Figure 5 shows the stages of the transmitter.

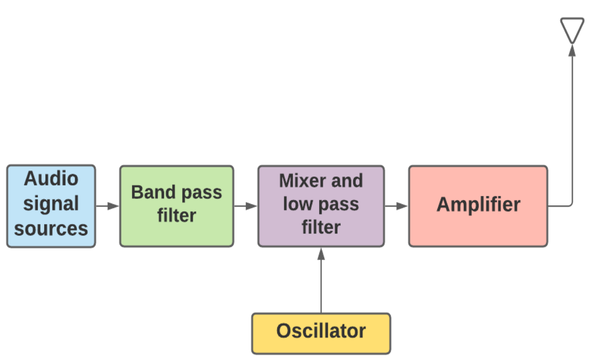

Fig. 5.Transmitter Block Diagram

The radio frequency signal generated by the transmitter is also known as a carrier wave that has a sinusoidal shape, and to transmit information, this wave can be modified in its phase, amplitude, and frequency parameters by a modulating signal; in this case, we will address to the modification of the frequency called frequency modulation, it should be noted that the carrier wave has the highest frequency as can be distinguished in Figure 6 and Figure 7.

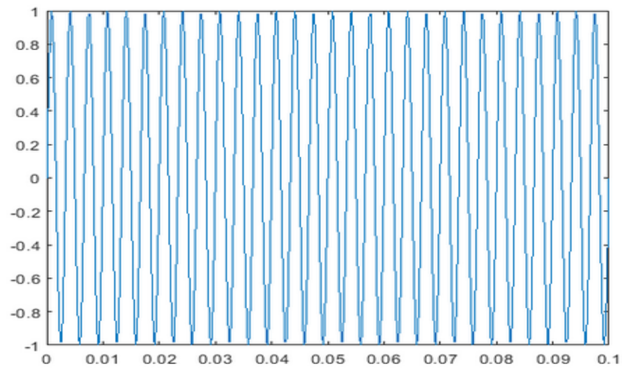

Fig. 6.Carrier wave

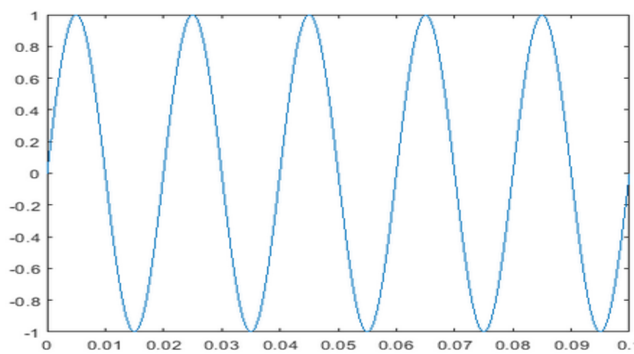

Fig. 7.Modulating signal

By modulating a signal, its spectral content is shifted in frequency, occupying a certain bandwidth around the frequency of the carrier wave. The modulating signal represents the information that we want to transmit using the radio frequency carrier signal, and the frequency modulation is carried out due to the advantages that this modulation technique presents, it is observed in Figure 8.

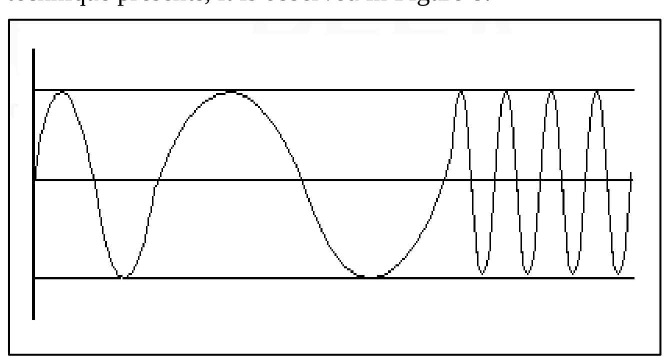

Fig. 8.Frequency modulated wave

The percentage of modulation is defined as the ratio between the real frequency deviation and the maximum frequency deviation allowed by law per 100% [10]. Stereo or mono systems should not exceed 100% on frequently recurring peaks. It is expressed as follows:

$$\% \text{ modulation} = \frac{\Delta f(\text{real})}{\Delta f(\text{max})} * 100\%$$

The modulation of the transmitter will be carried out through the satellite link of the National Radio station, a service that was implemented with the authorization of the Instituto Nacional de Radio y Televisión del Perú (IRTP) through Directorial Resolution N° 1095-2020-MTC/28[11]. The satellite to select is Intelsat 11, which is located at 14.63°S 69.44°W. This satellite is the one that provides signal coverage to Europe and America using the C band of transmission.[12]The following coverage footprint is observed in Figure 9.

Fig. 9.Intelsat 11 satellite coverage footprint

To make this link, it is necessary to take into account the location, horizontal displacement, elevation angle, angle with respect to the horizon, and direction of the receiving antenna [13]. For our case, the location will be in the same transmission plant in the place called "La Rinconada," so the same geographical coordinates will be used, and the satellite data is observed in Table IV.

TABLE IV. DETAILS FOR SATELLITE SIGNAL RECEPTION

Description	Data
Distance to the satellite	36735 Km.
Location	14.63°S 69.44°W
Elevation angle	55,1°
LNB tilt	59,60°
Azimuth	63,1°

The amplification of the radio frequency signal is to increase the power to provide signal coverage at greater distances, for which the transmitter power, the antenna gain, and the appropriate height are determined.

There are several kinds of radiofrequency amplification, such as class A, class B, class C, class AB. Its design responds according to individual cases. For our work, class C amplification will be used to meet the requirements for the use of the fundamental frequency with the minimum generation of harmonics.

The coupling of the transmitter and the antenna is fulfilled under certain parameters such as operating frequency, antenna length, height above sea level, impedance, transmission line attenuations, and connectors. These elements determine the good coupling for an efficient operation of the transmission system, avoiding losses and generation of return signals to the final radiofrequency amplification stage, increasing the temperature, and destroying the power semiconductor. The power measurement process in transmitters makes it necessary to create instruments that use special elements such as the directional coupler, a device that serves to independently take samples of the incident wave and reflected in a transmission line, as can be seen in Figure 10.

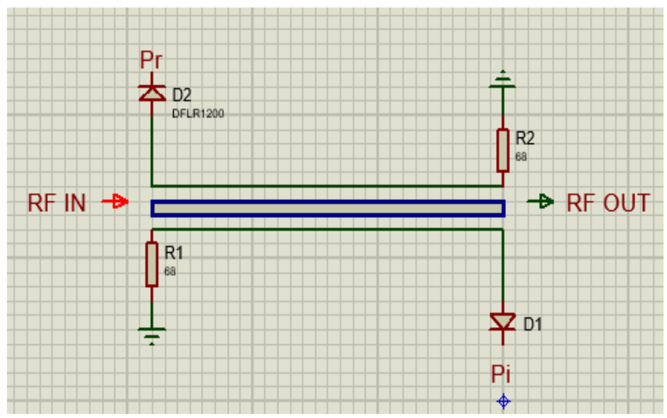

Fig. 10. High-frequency directional coupler

In a transmission line, the incident wave is the RF signal generated by the transmitter that propagates from it to the load or antenna. The reflected wave is the wave returned by the load towards the transmitter as a consequence of an impedance mismatch, as the load has a different impedance to the characteristic impedance of the transmission line [14]. These two waves traveling through the transmission line give rise to a standing wave of current and voltage along the line, whose relationship between the incident and reflected power captured by the directional coupler can be analyzed using the following Table V.

TABLE V. STANDING WAVE RATIO (SWR) AND ITS INCIDENCE

SWR	Reflected power %	Antenna power %
Infinity	100	0
17	80	20
9	63	37
6	50	50
3.5	32	68
3	25	75
2.3	16	84
2	10	90
1.4	3	97
1.2	1	99

Mathematical calculations are operated with the following expression:

$$SWR = \frac{1+\sqrt{\frac{Pr}{Pi}}}{1-\sqrt{\frac{Pr}{Pi}}} [15]$$

Where:

SWR = Standing Wave Ratio.
Pi = Incident power in antenna.
Pr = Power reflected in antenna.

Next, the calculation of the Apparent Radiated Power (ARP) will be carried out considering the losses caused by the different elements in the path until the power is delivered to the antenna; it is calculated through the following equation taking as a reference the indicated transmitter power in Table III.

Where:
ARP = Apparent Radiated Power
Pi = Incident power in antenna.
Pr = Power reflected in antenna
Pn = Nominal power of the transmitter
ALTx = Transmission line
Ac = connectors

ARP=150 Watts (w)
ARP = (Pi-Pr)*G_{antena}[13]

To find the Reflected Power (Pr), the following expressions must be calculated:

$$VSWR = \frac{1+ \left(\frac{Pr}{Pi}\right)^{\frac{1}{2}}}{1- \left(\frac{Pr}{Pi}\right)^{\frac{1}{2}}} [13]$$

Making a change of variable z=$\left(\frac{Pr}{Pi}\right)^{\frac{1}{2}}$, we obtain that: VSWR = $\frac{1+Z}{1-Z}$

Solving for Z
(1-Z) *VSWR =1+Z
VSWR-Z* VSWR=1+Z
VSWR-1=Z+Z* VSWR
VSWR-1=K (1+ VSWR)

$$Z=\frac{VSWR-1}{VSWR+1}$$

Knowing the antenna standing wave ratio (VSWR) = 1.3, we obtain:

$$Z=\frac{1.3-1}{1.3+1}$$

$$Z=\frac{0.3}{2.3}$$

Now squaring and doing the division:
$Z^2 = (\frac{0.3}{2.3})^2$
Z^2 = 0.0170132
Then:
Pr = Pi*0.0170132
Replacing in the equation:
PRA = (Pi-Pr) *G antenna
PRA = (Pi-Pi*0.0170132) *1
PRA = Pi (1 - 0.0170132)
Pi = $\frac{PRA}{1 - 0.0170132}$
Pi = 152.596W
Converting this value to dBw:
P(dBW) = 10. log10 ($\frac{p(W)}{1W}$)
P(dBW) = 10. Log10 ($\frac{152.596}{1W}$)
P(dBW) = 21.83543 dBw
Then:
Pi = Pn – ALTx – Ac
Pn = Pi + ALTx +Ac
Pn = 21.83543 dBw + 0.1701dB + 0.04dB
Pn = 22.40553 dBw
Pn = 174. 001503W

With the value of the nominal power of the transmitter (Pn), the tolerance of 2% provided by the manufacturer must be considered; this will make the nominal transmission power be within the limit values of:

Pn – 2% ≤ Pn ≤ Pn + 2%
174, 001503 -2% ≤ Pn ≤ 174, 001503 + 2%
170.521472W ≤ Pn ≤ 177,4815W

With the nominal power, ARP is calculated in each case, and it must be verified that the result is within the tolerance range of 10% of the ARP value allowed by the Ministerio de Transportes y Comunicaciones (MTC). [10]

135W ≤ PRA ≤ 165W

Taking the value of the nominal power of the transmitter:
Pn max = 177,4815W = 22,4915 dBw
Pn max ≤177,4815W
Pi = Pn max – ALTx – Ac
Pi = 22.4915 dBw – 0.1701dBm – 0.4dBw = 21.9214dBw
Pi = 155, 6467W
Pr = z^2*Pi
Pr = 0.0170132*155, 6467W
Pr = 2.64804W

ARP= (Pi - Pr) *G_{antena}
ARP = (155, 646W – 2.64804) *1
ARP = 152.997W
Taking the minimum value of the transmitter's nominal power:
Pn min = 170.5214W = 22,3177 dBw
Pn max ≥ 170.5214W
Pi = Pn max – ALTx -Ac

The value to be taken as our apparent radiated power will be the data that we will have to use in dB.

ARP (dBm) = 10 log ($\frac{150W}{1mW}$)

ARP (dBm) = 51.76dB

The proper use of the mentioned elements will make it possible for the power amplification stage to comply with its normal operation within the established parameters, and therefore at a normal temperature below 50°C. If for any reason, it exceeds 50°C, the alarms will be activated, and the equipment will automatically turn off.

III. RESULTS

To obtain the results, the Radio Mobile software is used, which allows us to carry out the simulation of the transmitter and receiver according to the established parameters of the different elements used for the propagation of the radio frequency signal. In addition, the different parameters obtained in the simulation will be analyzed to be able to contrast with physical equipment. The radiation power is shown through the heat map, whose signal coverage is represented by colors, the red color being a high-level signal of -66dBm, the signal coverage of the different areas such as the district of Cojata, the province of San Nicolas de Putina, the Kantati ururi community and many other neighboring towns that will also benefit from the radio broadcasting service and we can see it in Figure 11.

Pi = 22, 3177 dBw – 0.1701dBw – 0.4dBw = 21.7476
Pi = 149,5409
Pr = z^2*Pi
Pr = 0.0170132*149,5409w
Pr = 2.54416W
ARP = (Pi -Pr) *G_{antena}
ARP= (149.5409w – 2.54416) *1
ARP =146.9968w

With the previous calculations, it is revealed that, for a nominal power of the transmitter of 150W and with a tolerance of ± 2%, the maximum and minimum margin of the apparent power is within limits established by the MTC.[10]

135W ≤ PRA ≤ 165W
146.9968W ≤ PRA ≤ 152.997W

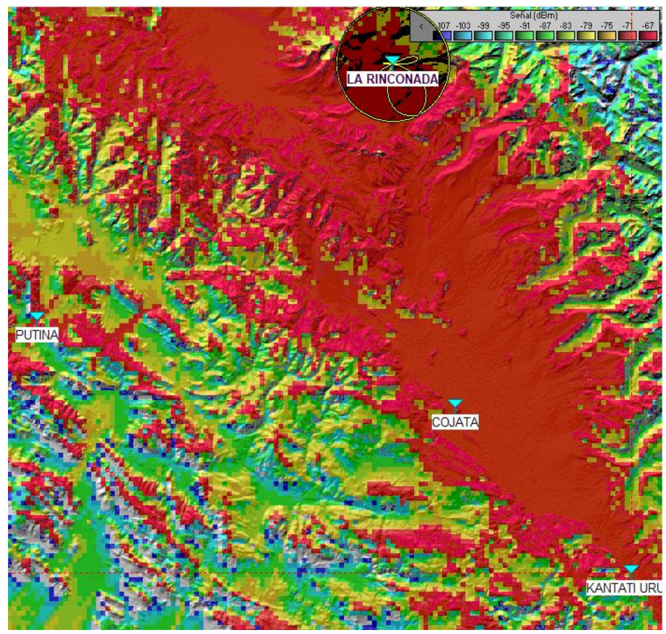

Fig. 11. Radiofrequency propagation heat map

To determine the appropriate level of reception, the classification ranges of the audible quality of the received signal are shown, as can be seen in Table VI.

TABLE VI. AUDIBLE SIGNAL

Signal quality	Range
Low	-75dBm- ∞
Medium	-70dBm- -74dBm
High	-69dBm and higher

In this simulation, which corresponds to the matrix located in the city called “La Rinconada” with respect to the town of Kantati Ururi, it is possible to observe and analyze the propagation of the radio frequency signal that transmits with a nominal power of 500W in frequency modulated at a distance of 71 km, the effective radiated power (PER) has a level of 680W and the equivalent isotropic radiated power (EIRP) of 1.12 Kw, very good levels that indicate a transmission in optimal conditions. In addition, the topographic profile does not show high reliefs between the Transmitter and Receiver; there is a line of sight, registering as the worst Fresnel equal to 1.0F1, which means 100% of the first Fresnel region is free of obstructions, thus allowing that the system has an adequate reception signal with a level of - 49.7dBm, being located at the level of high audible signal quality, as can be seen in the following Figure 12.

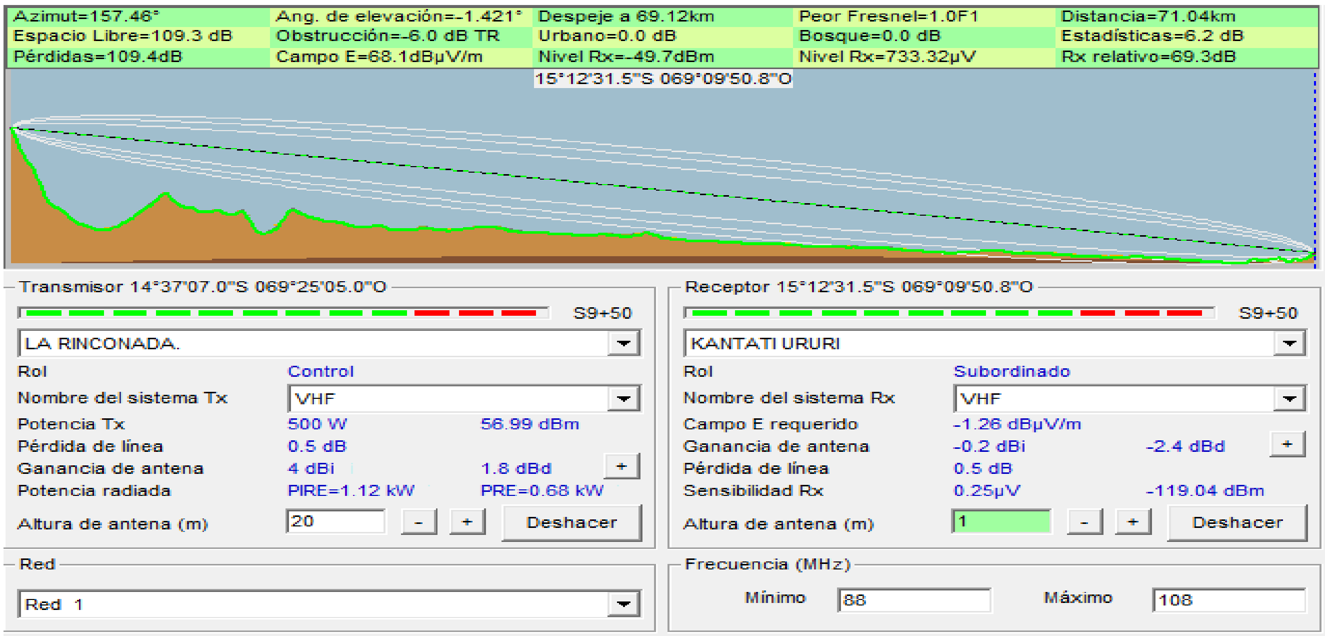

Fig. 12. Propagation of the electromagnetic wave from the "La Rinconada" transmission plant to the town of Kantati Ururi

A second simulation can also be observed, which corresponds to the transmission plant with respect to the district of Cojata, with the following results: the worst Fresnel zone equal to 0.7F1, indicating that 70% of the first Fresnel zone is free of obstructions and is within the allowed ranges, since at least 60% clear is required of the first Fresnel zone to obtain an adequate reception signal, as shown in Figure 13.

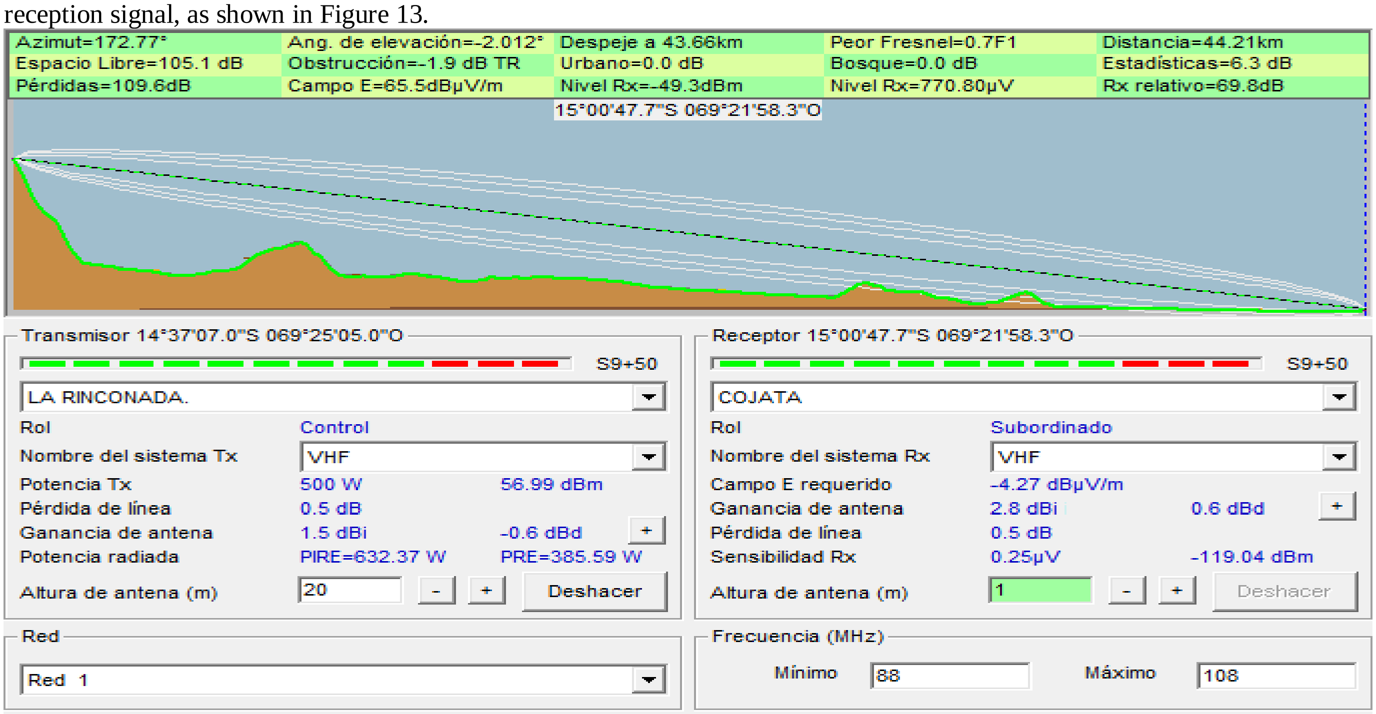

Fig. 13. Propagation of the radio frequency signal from the Transmission plant to the district of Cojata

The sensitivity of the receiver determines the level of the weakest signal that the receiver is capable of receiving with an acceptable reproduction of the original modulating signal; in the following Figure 14, the threshold of the receiver is observed.

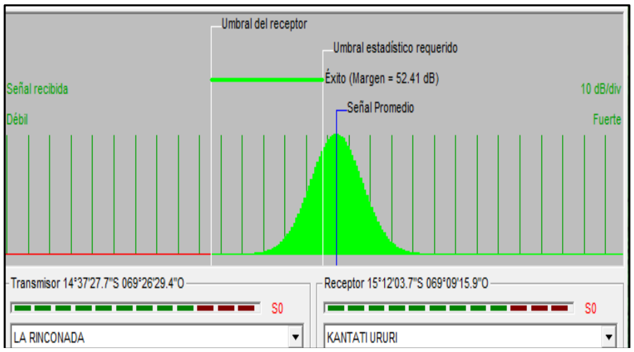

Fig. 14. Receiver sensitivity threshold

The coverage area of this radio station is aimed at signal coverage to the Kantati Ururi community and its surroundings, as shown in the figure on the heat map. According to the analysis of the simulations, they indicate that the field intensity is reaching different areas mentioned in a value greater than 46.9 dBuV/m, demonstrating adequate signal reception as shown in Table VII.

TABLE VII. SIGNAL QUALITY IN STRATEGIC AREAS

Zones	Signal quality	Power levels (dBm)
Kantati Ururi	High	-49.7
Cojata	High	-49.3
Putina	Medium	-68.6

IV. DISCUSSIONS

The research work [6]confirms that the use of radio communication media influences the cultural development of the inhabitants of rural areas where they have conventional devices of common use, such as the radio receiver, that is why this Research work presents an alternative method for the propagation of frequency signal modulated by the similar characteristics that our country presents due to the digital divide that mainly presents rural areas, so access to information is essential as part of social development and culture.

In [5], he considers that the Radio broadcast signal is an alternative to seek a change in behavior and an improvement in the quality of life, as it is a means of communication within reach of large groups, especially the population with limited economic resources.

In the simulations carried out, the height of the receiving antenna at a level of 1 meter was considered in comparison with the studies carried out by the antecedents. Otherwise, it is shown in [6]that for the simulation subjects, it places 20 meters in height in the receiving antenna, the simulation being far from reality.

The geographical characteristics of the area are rugged, so a detailed study must be carried out based on simulation software, which is not carried out in [7]because they pose up to a limit level of 60% free of the first Fresnel zone, which in our case was raised 80%.

In addition, the research work is oriented to the needs of the population with the peculiarity that it has the implementation of a receiver that will be linked to the satellite signal of the Instituto Nacional de Radio y Televisión del Perú (IRTV), which will avoid costs incurred in maintaining a transmission booth to broadcast live programs.

V. CONCLUSIONS

It is concluded that the radio is a means of social communication that is within reach of the great majority, so it facilitates the transmission of information, especially to the rural population with scarce economic resources.

The simulation through the software is essential because it allows determining effective communication through the line of sight and the reading of the parameters.

Keep in mind the Norms that regulate Telecommunications in our country when carrying out the implementation of Broadcasting projects.

It is concluded that the importance of simulation prior to implementation will help to visualize the characteristics of the antenna, as well as the Fresnel zone, the effective radiation power, and the reception signal level.

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