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Application of Linear Programming to Frequency Modulation Radio Signal Optimization in the High Frequency Band

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ABSTRACT ***Original research paper***

Efficient transmission and reception of Frequency Modulated (FM) radio signals are critical for maintaining high-quality broadcasting with minimal interference. This study presents a novel application of Linear Programming (LP) techniques to optimize the signal strength of an FM radio signal in a given geographical area, by modeling signal power levels and path loss as a set of linear inequalities, we develop an LP-based framework that seeks to maximize signal coverage and strength while minimizing the distortion the signal can be subjected to as a result of adverse weather conditions. Simulation results demonstrate that the proposed method significantly enhances signal clarity and reduces attenuation. The findings underscore the potential of linear programming as a powerful tool for spectrum management and signal optimization in FM broadcasting networks. The result of this research also depicts that, for an FM signal with a frequency band of 88-108 MHz with 1 W transmitted power, the signal strength must increase by 60% to compensate for the effect of increased temperature.

I. Introduction

Frequency Modulation (FM) radio remains a crucial medium for broadcasting, reaching millions of listeners worldwide. However, interference, bandwidth allocation, and signal strength optimization pose significant challenges for radio operators. To ensure high-quality transmission, mathematical optimization techniques such as Linear Programming (LP) can be applied. In communication networks, such as mobile wireless networks, measuring radio signal is an essential aspect of Resource Management for Radio services, which can be used for reliability assessment in mobile network systems, which helps in the planning of network coverage area development. Nonetheless, there is a possibility of applying these measurements rudimentarily without further crucial treatment; meanwhile, they are an indispensable source of information for the network [1].The introduction of high-quality multimedia services and the need for efficient use of the electromagnetic spectrum have driven the internet media to digital broadcasting [2]. Several digital transmission standards have emerged, each with unique technological applications. One of the widely adopted standards is the IBOC technology (NRSC-5), which enables a smooth transition from analog AM and FM radio to digital radio. However, the FM band, widely used in many countries, faces spectrum scarcity, hindering the growth of FM radio services [3].Optimisation is all about monitoring, verification, and improvement of the radio network performance [4]. The FM radio system must be continually monitored and optimized to enhance efficiency and generate income for the broadcasting station. To ensure continuous transmission in FM, it is essential to devise a method of optimizing the RF signal since the signal is easily obstructed along the transmission path. This article explores how LP can be used to optimize FM radio signals by minimizing interference, maximizing coverage, and improving overall efficiency.

The remaining sections of this article are as follows. Section IIhighlightsa review of the literature on FM radio transmission. Section III highlights the methodology, which includes the formulation of the LP model, the simulation setup, and the simple-based solutions were all presented. The results and discussions were presented in Section IV, and Section V concludes the article with insights on incorporating LP into practical spectrum-management workflows and outlines future extensions to multi-transmitter, multi-weather scenarios.

II. Review of Literature

FM radio transmission is receiving much more attention due to its higher level of loyalty. Research on the optimization of FM radio is still a novel technology. In [1], a novel approach was presented for manipulating and optimizing existing radio data in mobile wireless networks by utilizing an advanced signal processing approach to enhance mobile network performance. The work of [2] examined the optimization of digital resources for radio transmission over IBOC FM through the Max-Min Fairness. The research was focused on achieving fair resource distribution and providing sufficient service quality for each node in the RF network, by considering channel conditions and the types of traffic. A study in [3] explored optimization of the frequency modulation band, leveraging the Uganda Communications Commission (UCC).The work done by [4] was centered on the optimization of mobile networks with the aim of increasing the signal coverage of the radio network. The work in [5] optimized radio signal focusing onenergy-efficient application why under latency constraints, to determining the minimum latency threshold and examining the energy minimization case without latency limits. Researchers in [6] presenta study on cognitive radio leveraging spectrum management and fuzzy logic, which served as a decision variable, proposing a solution for interference mitigation and channel switches, while maintaining a good service quality.

In all, diverse attempts have been made by radio telecommunication researchers in understanding the effect of the weather compositions on radio signal attenuation; the bulk of such work is the tremendous study on the growth of wireless communication by [7]. The study emphasized wireless communication systems as a substitute for long-wired communication systems, along with the provision of a weather monitoring system at the FM band. The research concluded that knowing the effect of the weather components on wireless communication systems will provide room for the development of compact, robust, and resilient wireless communication networks under different weather conditions.

The study in [8] investigated the weather (temperature) effect on radio propagation at the 9 GHz band. The research employed the use of a patch antenna and a wave envelope, which were recorded for one hour. The study opined that radio signals varied significantly with temperature. Also, the work in [9] investigated the humidity, temperature, and pressure effects on FM signal strength, revealing that signal quality varied seasonally.

Given the review literature, the following gaps were identified: the work of [7], [8], and [9] did not examine the impact of real-time geo-environmental data on radio transmission optimization strategies. Also, [1], [2], and [5] focus on mobile networks or digital radio over IBOC FM where directly optimization of traditional FM transmission using signal processing techniques under real-world channel and environmental conditions and [9] evaluated signal strength under seasonal conditions, the study lacked a detailed geographical focus, and such context-based evaluations are rare in developing countries where infrastructure and climate variability significantly impact signal quality. Therefore, this article addresses these gaps and contributes to existing knowledge through the:

a. integration of Geo-Environmental Parameters into FM Radio Signal Optimization.
b. provision of a novel signal optimization Framework for Under-Researched FM Bands.
c. context specification in the evaluation of Signal degradation under seasonal variations in the developed region.

III. Methodology

1. Formulating the LP Model

To apply LP to FM signal optimization, the problem must be formulated as a linear program:

2. Decision Variables

Let:
P_j= power allocated to antenna configuration j, $j=1,2...m$
T = Temperature at different time of the day t, $t = 1, 2...m$
S_i= signal strength at location i, $i=1,2...n$
Z= minimum signal strength across all locations (to be maximized)
Given Data:
a_{ij} = signal contribution at location i from configuration j
P_{max} = total available transmitter power

3. Constraints

a. Signal strength at each location i is a linear combination of powers:

$$S_i = \sum a_{ij}P_j \qquad for\ all\ i \tag{1}$$

b. Ensure that each $S_i \geq Z$to maximize the minimum signal strength:

$$\sum a_{ij}P_j \geq Z \qquad for\ all\ i \tag{2}$$

c. Power constraint:

$$\sum P_j \leq P_{max} \tag{3}$$

d. Non-negativity:

$$P_j \geq 0 \qquad for\ all\ j \tag{4}$$

4. Objective Function

Maximize the minimum signal strength:

$$Maximise\ Z = -59.8\,x_1 - 71.9x_2 - 59.1x_3 \tag{5}$$

Subject to:

$$0.5x_1 + 0.75x_2 + 1.0x_3 \tag{6}$$

$$28.6x_1 + 31.0x_2 + 28.6x_3 \tag{7}$$

wherex_1, x_2, and $x_3$are constants called basic variables.

5. Implementation and Solution Method

The formulated LP model can be solved using the Simplex Algorithm. By running these algorithms, broadcasters can determine the optimal power levels, frequency allocations, and placement oftransmitters for maximizing efficiency. The flow chart is as shown in Figure 1.

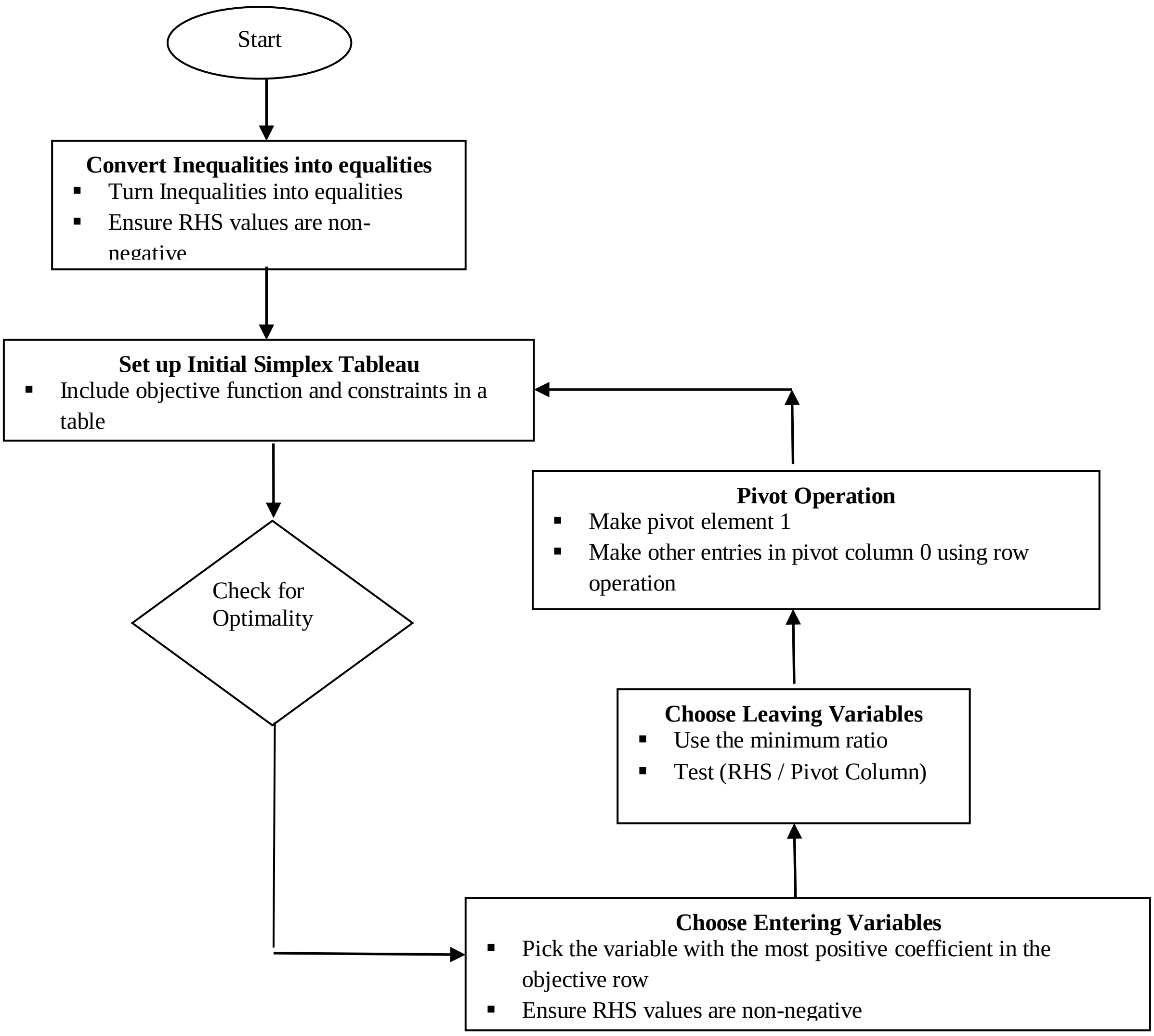

Figure 1: The Simplex Flow Chart Model Formulation

IV. Results and Discussions

The results of the field work carried out on the locally made transmitter with power (1Watt) and operating frequency band (88-108 MHz) were presented in Figures 2 – 4. The graphs of temperature and signal strength of the FM radio signal on the application the three different types of antennas, are separately shown in Figures 2 – 4. It can be deduced from the results that increased temperature has a slight effect on the signal strength of the FM radio signal.

Due to the ionization effect of the solar radiation on the layer of the atmosphere that serves as a reflector to the FM radio signal, some portions of the signals are scattered, and the resultant signal that reaches the required destination is reduced in strength. This practically indicates that the increased temperature slightly reduces the strength of the FM radio signal. However, from the results of the experiment carried out, the adverse effect of the increased temperature is minimal with the application of a wire monopole antenna.

As a result, optimization of the FM radio system was carried out using the LP method. It was observed that the signal strength was attenuated by 60%. Therefore, to compensate for the reduction, the signal strength should be increased in proportion to the level of attenuation.

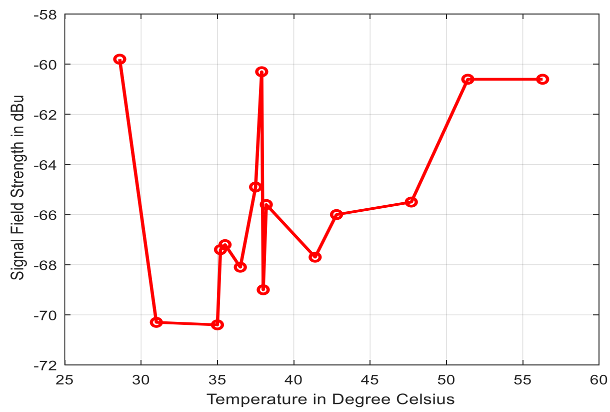

Figure 1: Graph of Signal Field Strength against Temperature on Day 1

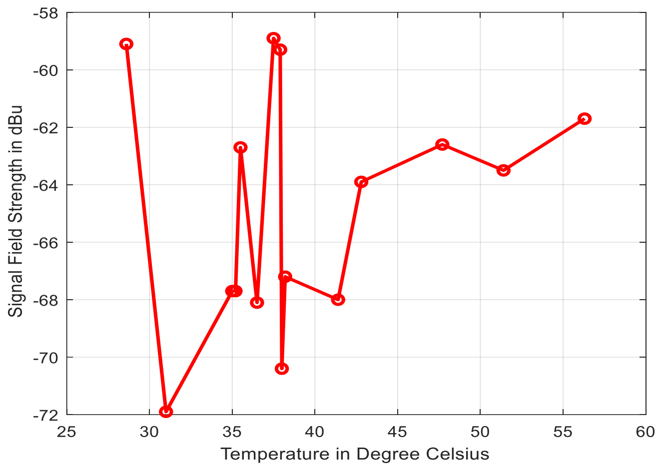

Figure 2: Graph of Signal Field Strength against Temperature on Day 2

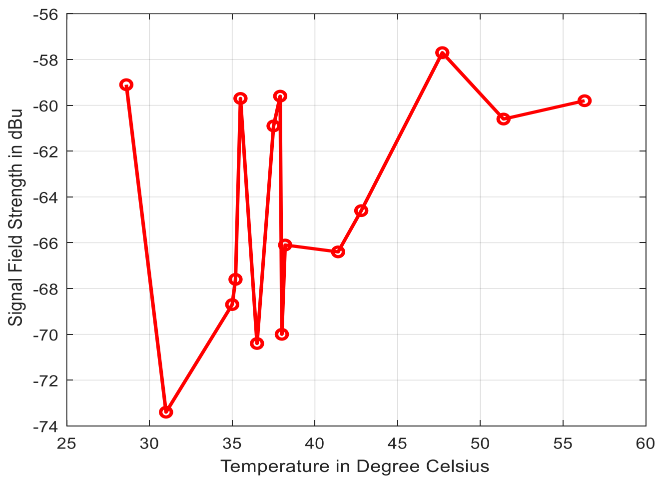

Figure 3: Graph of Signal Field Strength against Temperature on Day 3

V. Conclusion

The optimization of FM radio signals using Linear Programming presents a systematic approach to enhancing broadcast quality. By minimizing interference, maximizing coverage, and ensuring efficient resource allocation, LP helps FM stations provide superior service to listeners while adhering to technical and regulatory constraints. With advancements in computational power, LP-based optimization methods continue to play a vital role in modern broadcasting engineering.

In this research, it has been established that signal field strength plays a vital role in optimizing the FM radio signal. More importantly, with a transmitter of maximum power of 1 Watt operating within the frequency band (88-108 MHz), at minimum temperatures of 28.6°C and 31 °C, the signal field strength must be increased by 60% to annul the effect of attenuation.

References

1. Afef B. H. A., Alain L. C. and Eric M., "Optimization of radio measurements exploitation in wireless mobile networks", Journal of Communications, Vol. 2, No. 7, pp. 58-67, 2007.
2. Mónica R.M., Juan-Carlos V. F., Joel C. V., María C. R., Andres A. D. T. and William A. C. C., "Shapley's Value as a Resource Optimization Strategy for DigitalRadio Transmission over IBOC FM", Journal of Applied Science, pp. 1-18, 2024. [https://www.mdpi.com/journal/applsci]
3. P. Bogere, R.N. Akol, and 1. Butime, "Optimization of Frequency Modulation Band for Terrestrial Radio Broadcasting: The Case of Uganda", Department of Electrical and Computer Engineering, Makerere University, Uganda, pp. 1-6, 2015.
4. Olasunkanmi F. Oseni, Segun I. Popoola, Henry Enumah, Ayonote Gordian, "Radio frequency optimization of mobile networks in abeokuta, Nigeria for improved quality of service", International Journal of Research in Engineering and Technology (IJRET), Vol.3, No. 8, pp. 173-180, 2014.
5. Olga Mu˜noz, Antonio Pascual-Iserte, and Josep Vidal, "Optimization of Radio and Computational Resources for Energy Efficiency in Latency-Constrained Application Offloading", IEEE transaction on vehicular technology, pp.1-18, 2014.
6. Y Mimbeu, J Matanga, Y Malong, A Ngalle, J T Tasona Doko, J F Essiben, N Sévérin, O Raphaël, I Breunon, "Optimization Of Spectrum Management in A Cognitive Radio Network using Fuzzy Logic", International Journal of Engineering Research and Technology (IJERT), Vol. 11 No. 4, pp. 340 - 350, 2022.
7. P. K. Jayalakshmi and A. A .Pritviraj, " Real Time Weather Monitoring System with FM Channel". *IJAICT,* 1(1), 2014.(doi:01.0401/ijaict.2014.01.20 published Online 05(05)2014, ISSN:2348-9928).
8. Roshidah M., Marhamah M. S., Sabir A., Roslau U., Yew-Been S. and Nor-Hazmin S.,

"Temperature effect on the Tropospheric Radio Signal Strength for UHF Band at Terengganu", Malaysia. *Information Journal on Advances Science Engineering Information Technology,* 6(5), ISSN: 2088-5334, 2016.

9. Felix, A., Abdullahi, A., Olufemi, A., & Jaiyeola, O. P., " Effects of some weather variables on the signal strength of Maloney FM radio", Nasarawa State, Nigeria. *Heliyon*, *10*(5), 2024. (e25978. https://doi.org/10.1016/j.heliyon.2024.e25978)