*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

ISSN (online): 2581-3048

Volume 10, Issue 1, pp 34-38, January-2026

https://doi.org/10.47001/IRJIET/2026.101005

# Development of Low Frequency Radio Waves Transmitter for Emergency Telecommunication during Electromagnetic Disruption

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***Abstract* - The increasing threat of Electromagnetic Pulse (EMP) attacks and natural disasters on modern communication infrastructure necessitates the development of resilient and reliable telecommunication systems. Low frequency (LF) radio waves, particularly in the Very Low Frequency (VLF) and Low Frequency (LF) bands, offer a potential solution for maintaining critical communication capabilities during such events, as these frequencies are less susceptible to direct interference from high-frequency EMP components. This paper presents the design, development, and testing of a low-frequency radio wave transmitter specifically tailored for emergency telecommunication. The system leverages robust, EMP-hardened components, advanced shielding techniques, and power management strategies to ensure reliable operation in extreme conditions. Emphasis is placed on the transmitter's ability to maintain long-range communication over diverse geographical areas, particularly in military and maritime applications where traditional communication infrastructure may be compromised. The paper also explores the integration of redundant power sources, such as solar energy and battery backups, and highlights the potential for these low-frequency systems to support vital emergency communications in the aftermath of an electromagnetic disruption event. Experimental results demonstrate the transmitter's ability to deliver consistent, high-quality signals in both pre- and post-electromagnetic disruption environments, confirming its viability as a critical component in next-generation emergency telecommunication systems.**

***Keywords:*** Vacuum tube, LF radio waves, EMP attack, emergency communication, electromagnetic disruption.

## I. INTRODUCTION

A vast majority of modern day telecommunications relies on the use of radio waves of very high frequency, and thus a very short wavelength. The use of these frequencies allows for efficient transport of vast amounts of information and prevents distortions of this information. The high end of the radio spectrum cannot be challenged by alternative low frequency transmission of the same signal under normal circumstances due to the physical properties of such waves and the methods by which the information is encoded into these carrier waves.

During an Electromagnetic Pulse (EMP) attack, the goal is typically to disrupt or damage electronic devices and communication systems by generating a burst of electromagnetic energy. This energy can cause significant interference, rendering most modern electronic systems nonfunctional.

However, the impact on low-frequency transmissions depends on several factors, including the source and nature of the EMP, the frequency range being used, and the characteristics of the equipment in use.

### 1.1 EMP and Frequency Range:

EMP attacks are typically characterized by a wide spectrum of electromagnetic radiation, which can affect a broad range of frequencies. The EMP event can be broken down into three primary components, often referred to as E1, E2, and E3:

- E1: The initial, fast pulse that can disrupt or damage electronics, especially those in integrated circuits. It typically affects high-frequency systems.
- E2: A slower pulse similar to a lightning strike, which can damage electrical systems and power grids. It can also affect communication systems across a broad frequency range.
- E3: A slower, prolonged pulse that can cause long-term damage to electrical infrastructure, including power transmission lines and large systems, and can have an impact on low-frequency communication equipment.

### 1.2 Low-Frequency Transmission and EMP:

Low-frequency transmissions, often in the range of 30 Hz to 300 Hz (VLF - Very Low Frequency) or 3 kHz to 30 kHz

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(LF - Low Frequency), are less susceptible to the immediate effects of the E1 and E2 components of an EMP. However, the E3 component can still have an impact on these frequencies, especially if the transmission infrastructure is reliant on vulnerable electrical components like transformers and power lines.

- VLF and LF Communication Systems: These systems are commonly used for long-range communication (e.g., submarine communication, navigational aids, etc.). While EMP's E1 and E2 components might not directly impact these systems, the E3 component can induce currents in long cables or antenna systems, potentially disrupting or damaging transmission equipment.
- VLF and LF Antennas: Low-frequency antennas, especially those used for military or maritime communication, can be susceptible to damage if the EMP induces strong currents in the power systems or disrupts the amplifier and transmission equipment.
- Power Grid Vulnerabilities: Since low-frequency communication systems often rely on power grids (e.g., for powering transmitters or supporting infrastructure), an EMP induced power surge could damage critical components, such as transformers or power substations, potentially taking low frequency transmission systems offline.

### 1.3 Mitigation Strategies for Low-Frequency Transmission:

- Shielding: Proper electromagnetic shielding of key components (e.g., antennas, transmission lines, and power supplies) can reduce the impact of EMP by blocking the harmful radiation.
- Faraday Cages: Sensitive equipment can be stored or housed in Faraday cages, which block electromagnetic interference and reduce the likelihood of damage.
- Redundancy: Building redundant systems and infrastructure can help maintain communication even in the event of an EMP attack. For example, using satellite backup communication or low-frequency systems that are geographically isolated.
- Surge Protectors: Protecting power supplies with surge protectors can help mitigate the effects of EMP-induced power surges.

Low-frequency transmission systems are generally less affected by the high-frequency components of an EMP (E1 and E2) but may still experience disruptions from the slower E3 component, particularly if they rely on power grids or vulnerable infrastructure. The ability of low-frequency systems to continue functioning during or after an EMP attack depends heavily on the resilience of the underlying infrastructure, including the power systems and protective measures in place.

In a worst-case scenario, without proper protections or resilience plans, even low-frequency communication systems could be rendered inoperative, though they might have a slightly better chance of surviving than more modern, high frequency systems.

## II. WAVE PROPAGATION

The propagation of low frequency EM (electromagnetic) waves is different from high frequency EM waves in the sense that there is a larger amount of ways these waves interact with their surroundings.

### 2.1 High frequency (HF) electromagnetic (EM) waves

High frequency (HF) electromagnetic waves propagate through space by means of line of sight propagation. Therefore, any obstacle that is found between the transmitter and the receiver casts a shadow over the receiver, in other words blocks or reduces the intensity of the electromagnetic wave. The other most impactful limitation is that propagation of such electromagnetic waves is limited by the curvature of the Earth, where the line in sight is determined by the height of the transmitter antenna.

Such properties of HF EM waves are not usually considered limitations. The amount of cell and wifi towers is so large in the urban areas that propagation losses can be ignored and there is no need to have a large signal range on a signal antenna.

Problems arise if certain unpredicted changes in the environment happen. Strong storms, floods and other natural disasters can easily disturb and destroy certain antenna towers.

They can even make transmission at high frequencies completely unachievable due to the amount of particles absorbing electromagnetic waves during their propagation.

### 2.2 Low frequency electromagnetic waves

Electromagnetic waves of lower frequencies have two other means of propagation: a “ground wave” and a “sky wave”.

Ground wave propagation happens with low frequency waves with wavelengths ranging from several hundred meters to several kilometers. It is a means of propagation in which the waves travel through the surface of the Earth and even follow its curvature to an extent.

 

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Sky wave propagation happens with electromagnetic waves from several tens of meters in wavelength to a couple of hundred meters. Such waves are reflected off of the ionosphere of the Earth and can even bounce between the ground and the ionosphere several times, transversing large distances in doing so.

The range of a certain frequency of wave is dependent on the time of the day as the ionosphere width changes during the day.

## III. METHOD

### 3.1 Two-way communication

Due to the propagation characteristics of low frequency waves, low power transmitters can have significantly greater value in local wireless messaging than transmitters operating on high frequency. This is because the propagation of low frequency waves allows for less losses and greater range of the signal.

An alert system based on low frequency radio waves could allow not only for messages from a central transmitter to be heard in places affected by a disaster, but also allow these places to respond by using smaller transmitters that need not to be as specialized as professional radio transmitters.

Making these transmitters based on vacuum tubes could give them the advantage of being resistant to static discharge that would destroy solid state electronics.

### 3.2 Operating principle of low power vacuum tube signaling transmitter

Vacuum tube transmitter can be divided into three parts:

**1) Input signal amplification**

The input signal amplification can be any type of audio signal. This includes voice recordings, specializes distress tones and Morse code (Figure 1).

**2) RF carrier frequency generator**

This oscillator is based on a quartz crystal resonator. This has the benefit of being a stable source of the LF radio signal (Figure 2).

**3) Modulator and transmitter**

In this part the amplitude of the RF signal is modulated by the audio signal. This results in an amplitude modulated (AM) wave that can be received by any typical AM/FM radio (Figure 2).

The operating principle of a central transmitter would be very similar, but made to be able to produce much higher power.

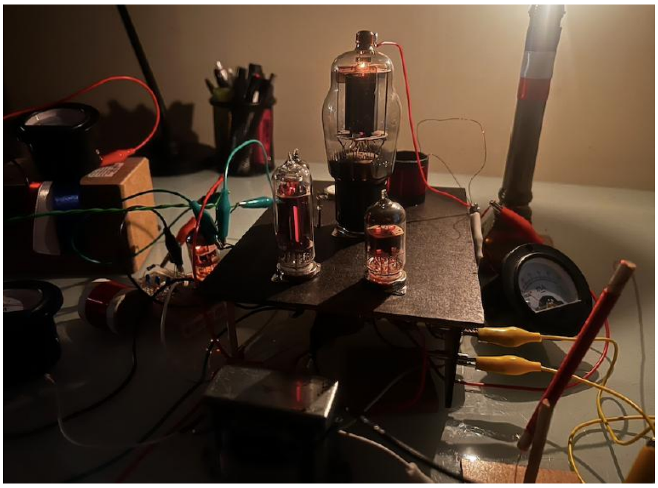

**Figure 1: Vacuum tube transmitter in operation during development**

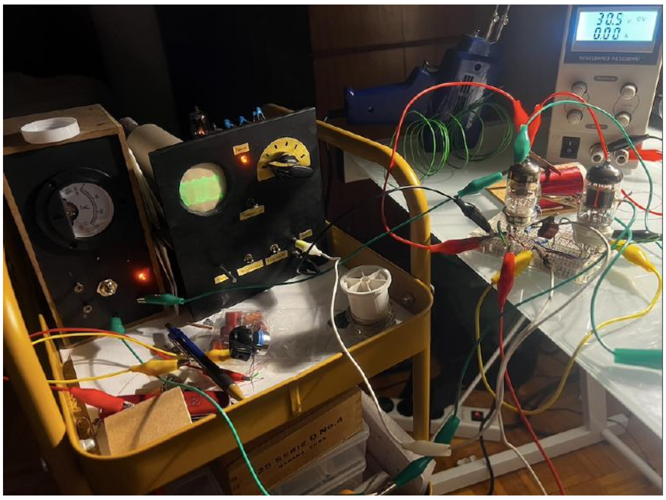

**Figure 2: Measuring RF modulation of circuit on vacuum tube oscilloscope during development**

## IV. RESULTS & DISCUSSION

### 4.1 Circuit for the vacuum tube transmitter

V2 is a high power pentode, A RF signal is input onto its control grid. Modulation is done by changing the plate and screen grid voltage.

V1 is a high power triode. A RF signal is applied to its control grid. The change in current flow through V1 causes a voltage change over the 15H inductor, allowing for modulation of the signal on V2. Such a circuit allows for 100% modulation of the RF carrier wave.

The RFC (RF choke) prevents the RF signal amplified by V2 from escaping back to the power supply. The RF signal is focused towards the antenna circuit.

 

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The values of C1 and C2 in the antenna circuit are chosen to form a resonant circuit at the RF frequency. C1 is variable to compensate antenna capacitance. The tuning of the antenna is done by monitoring current flow at point A and tuning C1 until a dip in the current is achieved (Figure 3).

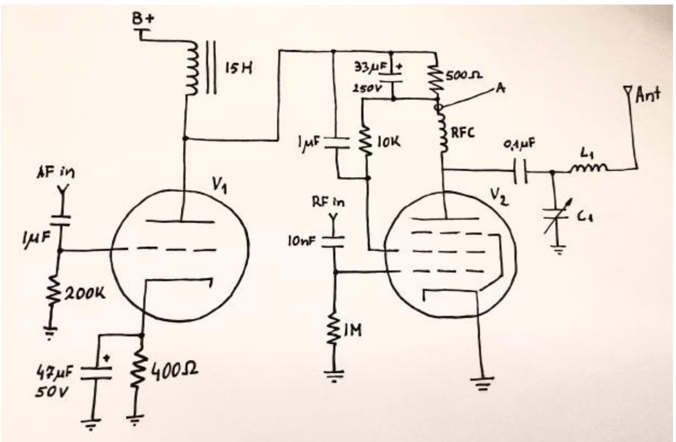


**Figure 3: Circuit for the vacuum tube transmitter**

### 4.2 The RF oscillator

The RF oscillator is a vacuum tube crystal driven oscillator. It is used as it provides a stable RF signal that has constant frequency. A LC oscillator cannot be used as it can change frequency during operation and due to slight changes in the surroundings. The variable capacitor is there to tune the circuit for optimal signal output. V3 is a low power triode vacuum tube. Any low power tube can be used for this purpose, including multi grid tubes (Figure 4).

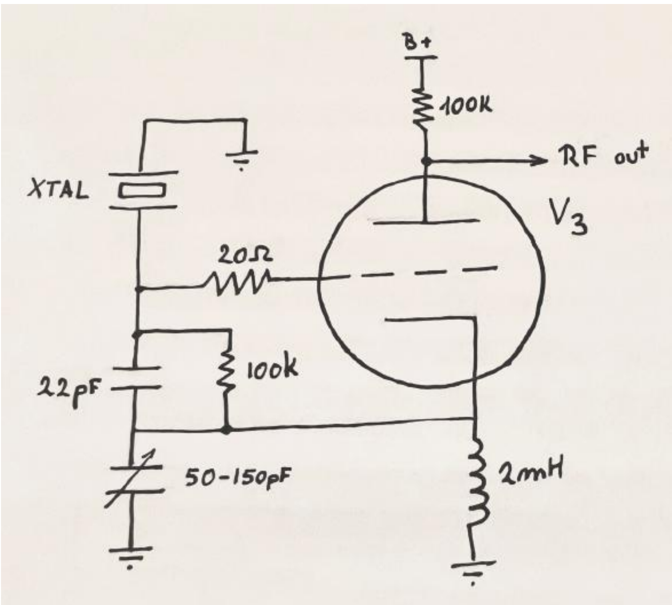


**Figure 4: The RF oscillator**

Figure 5 shows the low frequency modulation of RF carrier wave on crystal driven oscilloscope.

**Figure 5: Measuring low modulation of RF carrier wave on vacuum tube oscilloscope**

## V. CONCLUSION

Despite the superiority of the high frequency over low frequency electromagnetic waves for the transmission of information, in the case of natural disasters and emergency communication, low frequency waves prove to be more reliable than high frequency.

Low frequency propagation allows for information to be sent over long distances, harsh terrain and weather using a centralized transmitting site. In times of emergency this is more reliable than having a large amount of low power transmitters that are more vulnerable for failure.

Another benefit of making these transmitters based on vacuum tubes is that it gives them the advantage of being resistant to static discharge that would destroy solid state electronics.

## VI. RELEVANT SDGs

The development of a Low Frequency (LF) Radio Waves Transmitter for emergency telecommunication during electromagnetic disruptions can contribute to various Sustainable Development Goals (SDGs). Here are three relevant SDGs that align with this initiative:

### 6.1 SDG 9: Industry, Innovation, and Infrastructure

- Target 9.4 - "By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resourceuse efficiency and greater adoption of clean and environmentally sound technologies."
- Relevance: The development of low-frequency radio transmitters would directly contribute to advancing telecommunications infrastructure, especially in emergency situations. It ensures that communication

 

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systems are resilient and able to function even when higher frequency networks fail due to electromagnetic disruptions (e.g., solar flares, storms).

This enhances the overall technological innovation and robustness of the infrastructure.

**6.2 SDG 11: Sustainable Cities and Communities**

- Target: 11.5 - "By 2030, significantly reduce the number of deaths and the number of people affected by disasters, including water-related disasters, and increase the number of cities and human settlements adopting and implementing integrated policies and plans towards mitigation and adaptation to climate change."
- Relevance: Low-frequency radio communication is especially important for disaster response, as it can maintain contact in areas where other communication networks are down. Having a reliable means of emergency communication ensures faster and more effective disaster response, reducing the number of people affected and potentially saving lives during critical times.

**6.3 SDG 13: Climate Action**

- Target: 13.1 - "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries."
- Relevance: Electromagnetic disruptions (like solar storms) can severely impact satellite communication and GPS systems, which are crucial during natural disasters. Developing low frequency radio transmitters offers a climate-resilient alternative that can operate independently of vulnerable infrastructure, helping communities respond more effectively to climate-induced disasters.

These three SDGs highlight the importance of building resilient infrastructure, improving disaster preparedness, and addressing challenges posed by climate-related hazards. By focusing on this technology, societies can be better equipped to handle emergencies in an increasingly uncertain world.

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**AUTHOR'S BIOGRAPHY**

**Maximilian Aaron Jelačić** is a high school student with a strong passion for science, particularly in physics, chemistry, and mathematics. He has earned multiple awards in these fields, including several gold medals at the International Science Project Olympiad. Maximilian is also a national champion in both physics and chemistry. In his free time, he enjoys exploring electronics and conducting chemistry experiments.

**Citation of this Article:**

Maximilian Aaron Jelačić. (2026). Development of Low Frequency Radio Waves Transmitter for Emergency Telecommunication during Electromagnetic Disruption. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(1), 34-38. Article DOI https://doi.org/10.47001/IRJIET/2026.101005

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