Mathematical Analysis of Jamming of Radio-Controlled Improvised Explosive Device (RCIED)

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ABSTRACT

In military operations especially counter insurgency operations, many soldiers including the civilian population have lost their lives due to explosions from Radio Controlled Improvised Explosive Devices (RCIED). This research work examines mathematically the concept of jamming an RCIED. The wave equation and the principle of superposition of waves were used to show how destructive interference can annul the effect of RCIED. It is obvious from the graphical presentations that the destructive effect of the waves from the jamming device effectively brought the waves from RCIED to nullity (zero) as the two graphs collapse at the point $y = 0$..

INTRODUCTION

The use of Radio Controlled Improvised Explosive Devices (RCIEDs) is especially responsible for the alarming rise in global terror attacks, 62% of RCIED attacks now occur in densely populated areas. Statistics show that the number of RCIED-based terror attacks carried out by terrorist groups has increased by 40% in Nigeria alone over the past eleven years. The Madalla bombing in Niger State, Nigeria, was one of the worst attacks; an RCIED was also used in this terrorist act, according to the findings of the investigation into the attack.

The south-eastern part of the country is not also left from terror attacks. Most recently, an IED manufacturing factory was discovered. This substantiates the frequency of bomb attacks in that region. An attack occurred on the vehicle of a former state governor of the region; that heinous deed was carried out using an IED. Additionally, in the nation's North East, which is beset by terrorist attacks. The Nigerian Army has been the target of IED attacks most frequently. A high-ranking officer of the Nigerian Army stated in a Guardian Newspaper article that IEDs remain a threat in the North East and very challenging for the Army. The unfortunate circumstance has necessitated the use of jamming devices by the Nigerian armed forces as a countermeasure to thwart these attacks. One of the countermeasures being utilized by leaders at various levels in an escort, is to have a vehicle which contains a jamming device which shadows the fundamental vehicles to cancel any radio-controlled improvised explosive device nearby (NAN, 2018).

In military operations in the past, most especially counter insurgency operations in the North East of the country, many soldiers including the civilian population have lost their lives due to explosions of RCIED because there were no jammers in place to render harmless the transmission signal of the RCIED. With the introduction of Jammers, it is expected that the fatality effect of RCIED will be drastically reduced. The RCIED is made possible through the principle of radio wave which is the fundamental building block of radio communications. It is generated by a transmitter and then detected by a receiver. An antenna allows a radio transmitter to send energy into space and a receiver to pick up energy from space. Transmitters and receivers are typically designed to operate over a limited range of frequencies (Crisell, 1992).

To annul the effect of attack from RCIED, waves that are of different phase by $\frac{1}{2}$ period which will be minimum when the other is maximum provided they are of equal amplitude are produced and the result is destructive interference leading to complete annulment of the RCIED. The *principle of superposition* dictates that the combined wave is simply the sum of the interfering waves. As the fourth-dimension battlefield, a unique and significant component of modern combat is electronic warfare. The concept of interference is key in electronic warfare (Lin, 2019)

The aim of this study is to use wave equation to show the mathematical process involved in jamming a radio controlled improvised explosive device (RCIED). The wave equation is modelled as a transmitted wave or signal on the one hand and as a jamming wave or signal on the other hand. The resultant effects which will be

shown mathematically and graphically will later show the nullity of the effect of the RCIED.

Jamming
The intentional and deliberate transmission of signals for the purpose of interfering with, disturbing, distorting, exploiting, deceiving, masking, or otherwise degrading the reception of other signals that are used by radar/radio systems (Brunt and Leroy, 1978). The transmission of interfering wireless signals disrupts the existing wireless communications by lowering the signal-to-noise ratio at receiver sides, causing jamming in wireless network radio communication. (Grover *et al.*, 2014). Ashraf *et al.,* 2016 in their research defined jamming as the deliberate use of radio signals in order to disrupt any sort of communication under particular radio frequencies.

A convenient classification of jamming is by the ratio of the jamming signal to the acceptance bandwidth (Signal) of the victim equipment in this case, a radio controlled improvised explosive device. Jamming methods are usually classified as noise jamming and deception jamming. The active jamming techniques are regrouped into three categories based on various generation strategies: non-coherent jamming, convolution jamming, and multiplying jamming (Gong *et al.*, 2015).

Most of the time, GSM Jammers are used to jam the signal of an area. A GSM jammer is a device that transmit signals on the same frequency at which the GSM operates, the mobile telephones in the space where the jammer is found are disabled (Singh *et al.*, 2017). From observations, terrorist makes use of GSM to transmit signals to RCIED. A signal is a function that conveys information about a phenomenon. The term signal is used for referring to a wide variety of information. It could be an electromagnetic wave which is modulated to transport the output of a thermocouple which conveys temperature (Priemer, 1991). In telecommunications, it refers to any time varying voltage, current or electromagnetic wave that carries information. A signal can be audio, video, speech, image, sonar and radar-related and so on (Belattar, 2021).

The purpose of this study is to analyse the mathematical process involved in Jamming a Radio Controlled Improvised Explosive Device. The wave equation adapted from Sen, 2014 and Gerig 2021 is used to show the wave from the Radio Controlled Improvised Explosive Device (RCIED) and also the wave from the Jamming device.

MATERIALS AND METHODS
Mathematical Formulation
A wave equation is a second-order partial differential equation representing some medium competent in transferring waves. It always contains a second order derivative with respect to time derived from $F = m\frac{d^2 s}{dt^2} = m\frac{dv}{dt} = ma$ and a second derivative with respect to the position derived from $F = -kx$

Mathematically, the equation of wave is given as:
$$\varphi(x,t) = f(x - ct) \qquad (1)$$
The harmonic version of equation (1) is given as:
$$\varphi(x,t) = A\cos(kx - \omega t) \qquad (2)$$

Wave Equation of the Radio Controlled Improvised Explosive Device
Let
$$y_1 = A\cos(kx - \omega t) \qquad (3)$$
assume $k = \frac{2\pi}{\lambda}$ and $\omega = 2\pi f$
we have
$$y_1 = A\cos\left(\frac{2\pi x}{\lambda} - 2\pi f t\right) \qquad (4)$$
Since, $f = \frac{1}{T}$
$$y_1 = A\cos\left(\frac{2\pi x}{\lambda} - \frac{2\pi t}{T}\right) \qquad (5)$$
Assume a wave of amplitude, $A = 3m$, wavelength, $\lambda = 4m$ and speed of the wave, $v = 0.25m/s$ and $\pi = 180^0$.
Therefore, the wave equation becomes;
$$y_1 = 3\cos\left(\frac{2\pi x}{4} - \frac{2\pi t}{16}\right) \qquad (6)$$

Wave Equation of the Jamming device
Let
$$y_2 = A\cos(kx + \omega t) \qquad (7)$$
where $k = \frac{2\pi}{\lambda}$
we have
$$y_2 = -A\cos\left(\frac{2\pi x}{\lambda} - \omega t\right) \qquad (8)$$
Negative sign indicates that it is moving in opposite direction to the RCIED wave.
Similarly, $\omega = 2\pi f$ and $f = \frac{1}{T}$
$$y_2 = -A\cos\left(\frac{2\pi x}{\lambda} - \frac{2\pi t}{T}\right) \qquad (9)$$
The jamming wave can destructively interfere with the wave from the RCIED if and only if it has same amplitude with it.
Therefore, given the amplitude, $A = 3m$, wavelength, $\lambda = 4m$ and speed of the wave, $v = 0.25m/s$ and $\pi = 180^0$., the wave equation becomes;
$$y_2 = -3\cos\left(\frac{2\pi x}{4} - \frac{2\pi t}{16}\right) \qquad (10)$$

Applying the principle of superposition, we have
$$y = y_1 + y_2 \qquad (11)$$
where y is the resultant effect of the interaction of waves y_1, y_2.
Recall
$$y_1 = A\cos(kx - \omega t) \qquad (12)$$
and
$$y_2 = A\cos(kx + \omega t) \qquad (13)$$

and moving in opposite direction, we have:

$$y_1 = A\cos(kx - \omega t) \qquad (14)$$
$$y_2 = -A\cos(kx - \omega t) \qquad (15)$$

where the negative sign in y_2 shows that it moves in opposite direction to y_1

∴ equation (11) becomes

$$y = [y_1 + (-y_2)] \qquad (16)$$
$$y = A\cos(kx - \omega t) + [-A\cos(kx - \omega t)] \qquad (17)$$
$$y = A\cos(kx - \omega t) - A\cos(kx - \omega t) \qquad (18)$$

$$y = 0 \qquad (19)$$

RESULT AND DISCUSSION

The graphical representation of the waves emanating from the RCIED is depicted in Figure 1. In plotting the graph, the following values were assumed: amplitude, $A = 3m$, wavelength, $\lambda = 4m$ and speed of the wave, $v = 0.25m/s$ and $\pi = 180^0$.
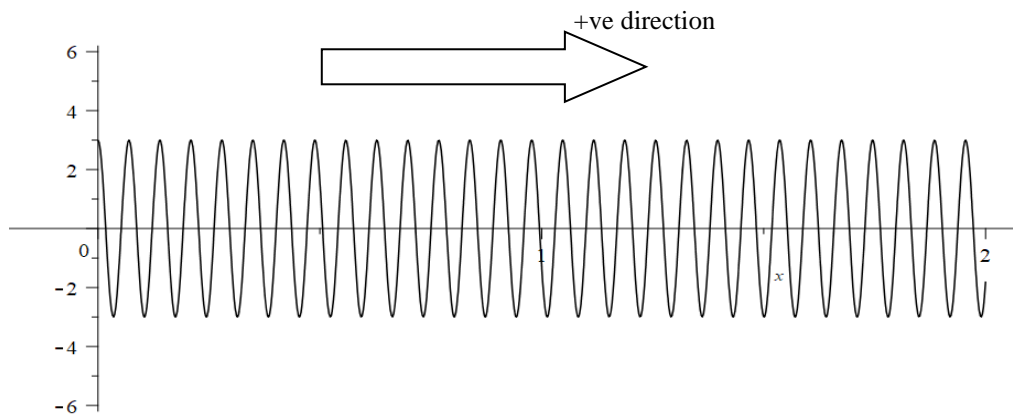

Figure 1: Wave-Form of the Radio Controlled Improvised Explosive Device (RCIED)

The graphical representation of the waves emanating from the jamming device is depicted in Figure 2. In plotting the graph, the following values were assumed: amplitude, $A = 3m$, wavelength, $\lambda = 4m$ and speed of the wave, $v = 0.25m/s$ and $\pi = 180^0$.
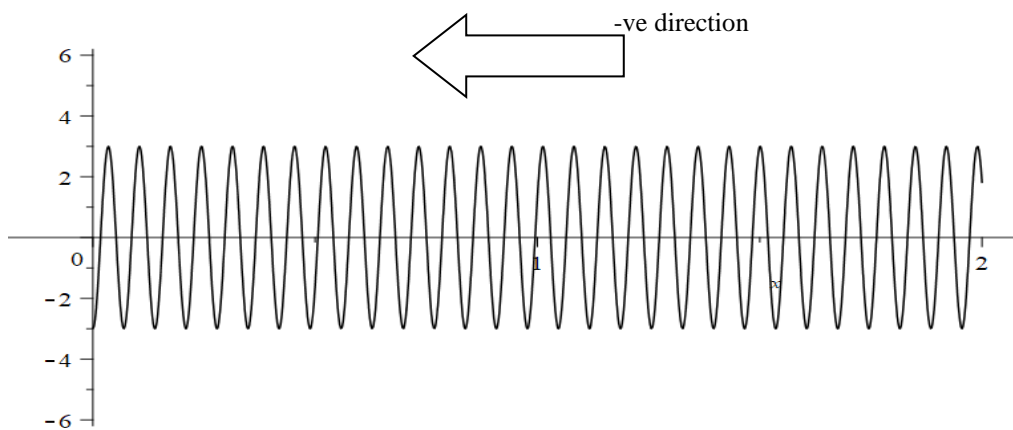

Figure 2: Wave-Form of the Jamming Device

From Figure 2, it can be seen that the wave travels in opposite direction to the wave of the Radio Controlled Improvised Explosive Device but with the same amplitude.

The graphical representation of the resultant effect of the interference of the jammer with the RCIED is depicted in Figure 3.
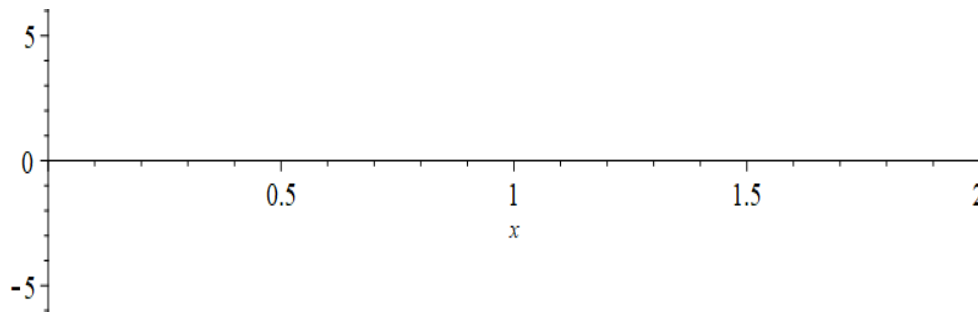
Figure 3: Graphical Representation of the interference of both waves

Figure 3 shows that the effect of the interference has brought the power of the attacking or transmitting signal to zero (nullity) since, $y = 0$. This also shows the destructive interference of the waves which produces zero amplitude, or complete cancellation, at all points. The two waves exactly cancel each other out and there is no effect and no energy transferred. For this to occur, it requires precisely aligned waves from the jamming device.

CONCLUSION
This research work shows that the concept of jamming can be explained mathematically. One of the fundamental equations used to explain jamming is the wave equation in equation (2). Since an RCIED cannot be triggered except by transmission of waves, equation (2) is simulated as wave which can be read as a signal from the RCIED and also as the wave equation of the jamming device travelling in the opposite direction. The simulated wave equation of the RCIED in equation (4) and the simulated wave equation of the jamming device in equation (8) are shown mathematically after interference using the principle of superposition of waves, the result obtained in equation (19) is $y = 0$ which implies that the effect of the interference has brought the power of the attacking or transmitting signal to zero (nullity). Figure 3 shows graphically the destructive interference of the waves which produces zero amplitude, or complete cancellation, at all points.
As a result of successful interference in Figure 3, it is shown that the jamming wave or signal is capable of effectively nullifying any propagating wave or signal from an RCIED. This research work has further laid credence to the fact that harmful or disruptive signals can be effectively annulled. An example of this is the Radio-Controlled Improvised Explosive Device. It should be of note that the Jamming device can stop the RCIED from a reasonable distance.
From this research work, the best way to counter or cancel the effect of an RCIED is by jamming its transmission. In the North East of Nigeria ravaged by insurgents, the use of Jammers will be effective in counter insurgency operations. The effect of using jammers will also reduce the mortality rate of soldiers and most especially the civilian population in that area.
Also, jamming can be used for protection of executive office holders in the country. Most especially when they are in a convoy in volatile areas of the country. A jamming device should be among the convoy of vehicles so as to annul the effects of any RCIED in the area.
Jamming devices should be placed at high value targets in the country such as Malls, Markets, Schools, Religious Worship Centers, government offices etc. so as to avoid attacks from non-state actors.

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