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Application of Vibrational Resonance to Solve Call-Drop Issue Experienced in Telecommunication.

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Abstract

One of the biggest problems nowadays for network operators are recurring call drops. The number of subscribers has tremendously increased over the years; the quality of service (Call Drop Rate) has become an issue to consider as many subscribers are not satisfied with the services rendered. There are various causes of call drop in telecommunications such as Electromagnetic causes, Irregular user behavior, abnormal network response and others. Over 50% of call drops are caused by electromagnetic strength fluctuations such as power attenuation, deep fading and so on. In this paper vibrational resonance (VR) is proposed as a strategy towards solving the aspect of call drops caused by power attenuation. Attenuated amplitude modulated (AM) signal, with frequency '

1. Introduction

Call drop in telecommunication occurs when a call gets abruptly disconnected before the caller party or called party finishes their conversation and one of them hung up. This issue of undesirable termination or disconnection is known as call drop. The number of subscribers in telecommunication services continues to increase by the day and this effect an immense load on the infrastructure which causes a dip in the quality of services provided by the service providers Pradeep *et al.,* (2016). One of the most important qualities of service indices for monitoring performance of cellular networks is the drop-call probability Shiri, and Berang, (2020), Nilesh and Jyoti (2016). Consequently, mobile phone operators apply many optimization procedures on several service aspects for its reduction. As an example, they maximize service coverage area and network usage; or they try to minimize interference and congestion; or they exploit traffic balancing among different frequency layers (e.g., 900 and 1800MHz in the European GSM standard).

There are several papers which study performance in cellular networks and, in particular, how the drop call probability is related to traffic parameters. Gennaro *et al.,* (2007) studied classification of call drop causes using data that was collected over a period of 2 years in different network areas. The following was reported;

Electromagnetic causes (51.4%), Irregular user behavior (36.9%), abnormal network response (7.6%) and others (4.1%) Gennaro *et al.,* (2007). Furthermore as reported by Pradeep *et al.,* (2016) some of the causes of call drop are;

a. *Demand of wireless cellular connectivity*
b. *Signal strength* - When a user enters an area which is out of coverage or having inadequate signal strength or the place where the signals are interfered,

interrupted or jammed may cause call drop. This is like leaving the coverage area. Occasionally calls are dropped during handover or handoff procedure between cells. This is due to traffic imbalance in the cell site, when one cell site is handoff a call to another cell site and it's having its maximum capacity then call drop take place.

c. *Network Configuration*

d. *Transmission Problems*

e. *Trans-receiver and receiver problem*

f. *Propagation factors*

Alessandro *et al.,* (2013) investigated call drops with field measurements in commercial mobile phones. They presented a new methodology to investigate call drops by using mobile phones to do the measurements following the concept of *citizen sensing*. A mobile application for Android was made that collected all necessary data and dumped the measurement results in a centralized database where the measurements were evaluated and represented on Google Maps. With a post analysis of the measurements, a classification of the call drops results was made. A case study of Nigeria's GSM sector was carried out by Rex (2015) he investigated the quality of service of GSM networks in Nigeria using the call drop rate and the call handover success rate as the key performance indicators. The analysis showed that GSM services in Nigeria were unreliable. Cell splitting, sectoring, and efficient resource management were highlighted as the possible means of maximizing the networks' quality of service when implemented.

Chidera *et al.,* (2015) proposed the reduction of call drop due to high bit error rate (BER), by using a new signal processing subsystem at the receiver section of a wireless system. It was found that this subsystem helped to improve the BER and hence the end-to-end performance of the system. The effect of this signal processing block was explored by considering Additive White Gaussian Noise (AWGN), Ricean Fading and Channel Coding. The implication of this was that the existing network will see a reduction in call drops. The results showed a coding gain of 3dB.

Olaonipekun *et al.,* (2019) presented the Artificial neural network approach to predict call drop during an initiated call. GSM parameters data for the prediction were acquired using TEMS Investigations software. The developed model had an accuracy of 87.5% prediction of drop call. The developed model was both useful to operators and end users for optimizing the network. In this paper a solution to call drop due to electromagnetic causes such as signal attenuation is proposed. The attenuated signal is applied to a duffing oscillator and a low frequency signal is added in order to obtain vibrational resonance of the input signal as shown by Landa and McClintock (2000). Stochastic resonance phenomenon can be realized when a bi-stable or multi-stable system is driven by a weak periodic force and additive noise of appropriate intensity Rajasekar and Sanjuan, (2016).

Injection of noise to a nonlinear system, through a cooperative interaction, brings assistance to the weak signal in eliciting a more efficient response by overcoming a potential barrier or a threshold. When the noise term used to observe stochastic resonance is replaced by a high frequency force and the amplitude or frequency of the high-frequency force is varied, a non monotonic variation of the amplitude of the output signal at the low-frequency of the input signal is achieved. Specifically, the amplitude of the output signal increase from a small value reached a maximum at one or two critical values of the control parameter and then decayed. Since this phenomenon is induced by a relatively high-frequency force at the low-frequency of the input signal, it is termed vibrational resonance.

2 Methodology

The concept of vibrational resonance is deployed as a strategy towards solving the problem of call drop due to electromagnetic causes such as signal attenuation. The attenuated signal is
6 applied to a duffing oscillator as the low frequency signal and a high frequency signal is added in order to obtain vibrational resonance of the input signal. Here the attenuated signal is an AM signal.

2.1. The Model

The model in this work is a duffing oscillator given as;

$$\ddot{x} + p\dot{x} + \omega_o^2 x + \beta x^3 = f\sin\omega t + g sin\Omega t \qquad (2.0)$$

Driven by a bi-harmonic force (frequencies ω and Ω) with sharp variation in frequency ($\Omega \gg \omega$) is given. 'p' is the damping term. $V(x)$ is the potential, 'f' is the amplitude of the low-frequency force and 'g' is the amplitude of high-frequency force.

Where $$V(x) = \frac{1}{2}\omega_o^2 x^2 + \frac{1}{4}\beta x^4 \qquad (2.1)$$

The AM signal is given as $f sin\omega t$ where 'ω' is the frequency of the carrier and $f = V_c + V_m sin\omega_m t$ where V_c is the amplitude of the carrier, V_m the amplitude of the modulating signal and ω_m is the frequency of the modulating signal so that the full AM signal is

$$(V_c + V_m sin\omega_m t) sin\Omega t \qquad (2.2)$$

Given the condition $\Omega \gg \omega_m$ where ω_m is a low frequency

As a result of the difference in time-scales the solution to (2.0) consists of a slow motion $x(t)$ with period $\frac{2\pi}{\omega}$ and a fast motion $\psi(t, \tau = \Omega t)$ with period $\frac{2\pi}{\Omega}$ i.e.

$$x = X + \psi \qquad (2.3)$$

The mean value of the fast motion is

$$\langle \psi \rangle = \frac{1}{2\pi} \int_0^{2\pi} \psi d\tau = 0 \qquad (2.4)$$

Using equations (2.3) and (2.4) in (2.0) yields;

$$\ddot{X} + d\dot{X} + (\omega_o^2 + 3\beta\langle \psi^2 \rangle)X + \beta X^3 + \beta\langle \psi^3 \rangle = f \sin \omega t \qquad (2.5a)$$

$$\ddot{\psi} + d\dot{\psi} + \omega_o^2\psi + 3\beta X^2(\psi - \langle \psi \rangle) + 3\beta X\left(\psi^2 - \langle \psi^2 \rangle\right) + \beta\left(\psi^3 - \langle \psi^3 \rangle\right) = g sin\Omega t \qquad (2.5b)$$

Equation (2.5) gives the equation of motion for the fast and slow motion respectively

Using the inertial approximation, $\ddot{\psi} \gg \dot{\psi} \gg \psi$ Equation (2.5b) can be approximated to: $\ddot{\psi} = g sin\Omega t$, which has the solution

$$\psi = \frac{-g}{\Omega^2} cos\Omega t \qquad (2.6)$$

Keeping approximation (b) in mind it follows that

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$$\langle \psi \rangle = 0 \ , \langle \psi^2 \rangle = \frac{g^2}{2\Omega^4} \ , \langle \psi^3 \rangle = 0 \qquad (2.7)$$

Using (2.7) in (2.5a)

$$\ddot{X} + d\dot{X} + \left(\omega_o^2 + 3\beta \frac{g^2}{2\Omega^4}\right) X + \beta X^3 = f \sin \omega t$$

$$\ddot{X} + d\dot{X} + C_1 X + \beta X^3 = f \sin \omega t \text{ wh ere } C_1 = \omega_o^2 + 3\beta \frac{g^2}{2\Omega^4} \qquad (2.8)$$

Equation (2.8) can be viewed as the equation of the system with effective potential

$$V_{eff} = \frac{1}{2} C_1 X^2 + \frac{1}{4} \beta X^4$$

From (2.8) we can see that the by varying parameters g and Ω of the fast dynamics the slow dynamics of the system can be modulated.

For $f \ll 1$, given $\omega_m \ll \omega$ so that $(V_m sin\omega_m t)(sin\omega t) \ll V_c sin\omega t$ (the signal has been greatly attenuated before being applied to the system) we assume that $|X| \ll 1$ for $t \to \infty$ and thus neglecting the nonlinear terms in equation (2.8), the solution becomes

$$A_L = \frac{f}{\left[\left(\omega_r^2 - \omega^2\right)^2 + d^2 \omega^2\right]^{\frac{1}{2}}} \qquad (2.9)$$

Where $\omega_r^2 = C_1$

To characterize vibrational resonance we define the response amplitude as

$$Q = \frac{A_L}{f}$$

$$Q = [(\omega_r^2 - \omega^2)^2 + d^2\omega^2]^{-\frac{1}{2}} \qquad (2.30)$$

Equation (2.30) is the expression for the response amplitude which vibrational resonance can be studied from.

3 Results and discussions

Figure 1a presents the plot of the response amplitude Q against the amplitude of the high frequency signal g for the values $\omega_o^2 = 1,\ \beta = 1, d = 0.5, f = = 0.1,\ \omega = 1.5\ and\ \Omega = 15$, while Figure 1b shows the plot of the response amplitude for values of g = 10, 100, and 200 respectively.

From equations (2.5a) and (2.5b) it is clear that the equation of motion for the slow dynamics depends on parameters of the fast input signal. Equation (2.30) shows that the response amplitude for the slow dynamics of the system depends on parameters of the high frequency input signal. The low frequency signal is an AM signal. Given some conditions on the signal, its response amplitude in the system can be modulated by parameters of the high frequency signal.

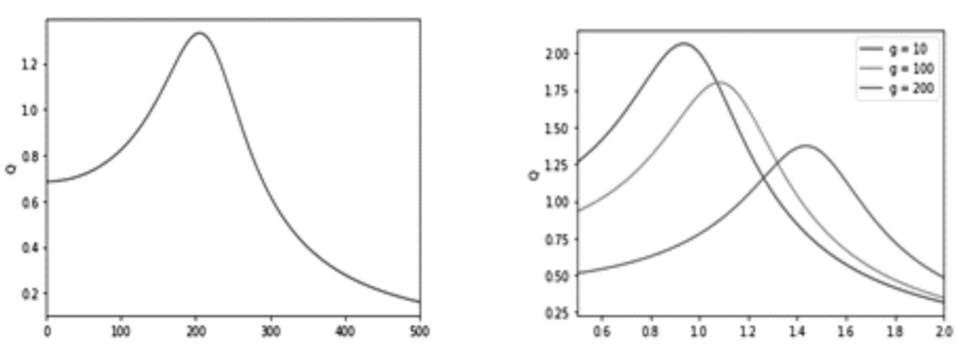

Fig 1: (a) plot of the response amplitude Q against the amplitude of the high frequency signal for the values $\omega_o^2 = 1,\ \beta = 1, d = 0.5, f = 0.1,\ \omega = 1.5\ and\ \Omega = 15$ (b) plot of the response amplitude for values of g = 10,100 and 200.

4 Conclusion

In this paper the method of vibrational resonance has been demonstrated as a way to amplify a weak AM signal in order to eliminate call drop associated with weak signal strength. The Dropped Call Rate is one of the key performance indicators currently used to evaluate the efficiency and effectiveness of the network operators. The AM signal was applied as the weak signal input with a low frequency to the duffing oscillator while a high frequency signal is also applied in order to achieve vibrational resonance. In Fig 1 (a) and (b) it is shown that the response amplitude Q of the low frequency (the AM signal) signal can be modulated by varying the amplitude g for the high frequency signal. From fig 1b it is observed that the frequency w at which resonance occurs for the weak signal can be varied by adjusting the parameter g.

The rise in dropped call rate is very worrisome and requires urgent attention to ensure that mobile phone users realize the value for their high service charges by the network operators. The implementation of this vibrational resonance concept in enhancing the signal strength in order to avert call drop will bring customer satisfaction with the service providers.

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