Global Scientific JOURNALS

GSJ: Volume 9, Issue 5, May 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

Harmonic Reduction in GSM Communication System in Nigeria

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ABSTRACT

Harmonic is a signal whose frequency is an integral multiple of the fundamental frequency resulting in distortion of supply of signal due to interference by superposition. In Global system for mobile (GSM), communication, Harmonic distortion retard the strength of a signal, and thereby creating interference in the signal. A pass-band filter for harmonic reduction in a cellular mobile phone was design and simulated. Mathematical approach was derived from first principle to have a transfer function and used to synthesis the design of the component. The bandwidth of the filter range is 890MHz to 915MHz for uplink communication. Matlab Simulink was used to model and simulate the filter. Analytical and simulated Bode plots were used for comparative analyses of the cellular mobile phone in term of quality factor, Bandwidth, signal strength, selectivity and dissipation factor. These shown, the analytical is more accurate with a quality (Q.F) and dissipation (D.F) factors of 42.93 and 0.023 respectively. More ever, The higher the Q.F and smaller the D.F, the better the filter. The various network provider should synchronize their GSM dissipation factor to a range between 0.020 and 0.024 in their systems so as to reduce harmonic distortion in communication system.

Keywords: Bandwidth, Harmonic, distortion, Congestion, Interference

1. INTRODUCTION

In communications system, the transmitted signal is subject to various impairments caused by the transmission medium combined with the mobility of transmitters and receivers. Path-loss is an attenuation of the signal strength with the distance between the transmit and the receive antennas, and the frequency reuse technique [9].

Cellular mobile phone standard in Nigeria uses frequency ranges of 890MHz - 915 MHz as the uplink frequency and (935-960) MHz as downlink frequency. The fast growing population of Nigerians has overgrown the limit of this bandwidth [6]. Furthermore, the presence of harmonics in communication system has a wide ranging effect on dissemination of supply information. These Include: Interference in Communication system and degradation of equipment performance and effective life.

In cellular mobile communication system, interference is anything which modifies, or disrupts a signal as it travels along a channel between a source and a receiver [4]. These term typically refers to the addition of unwanted signals to a useful signal. Common examples are:

Electromagnetic Interference (EMI), Co- Channel Interference (CCI), also known as crosstalk and Adjacent-channel Interference. Degradation of Equipment Performance and Effective Life .
Harmonics degrade the performance of equipment sensitive to signal quality causing productivity losses, expenditure in service, and additional capital expenditure in replacing life-span of communication equipment. Noise and distortion are the main limiting factor in communication and measurement system [8]. The major concern in this work is the effect of harmonics on communication system, particularly Global System for Mobile (GSM) Communication.
The major causes of harmonic distortion in GSM phone is low Bandwidth and Congestion.
Congestion: Congestion is a phenomenon in telecommunication system that occurs when more subscribers attempt simultaneously to access the network than it is able to handle [2]. This is a situation where subscriber numbers has completely overgrown network capacity.
Reasons for network congestion are:

- Lack of Adequate Channels: Since there are not enough base stations, automatically, there will be a lack of adequate channels to support the subscribers and the service rolled out by these operators. The channels determine the total number of subscribers that can be allowed to use a base station simultaneously at any point in time. This trend remains the same because any time a base station is added to their network; a high-level of promotion will be rolled out in order to attract more customers.
- Competition for Subscribers Among the Operators: It seems the highest priority of the GSM operators in Nigeria is the total sum of money they will make from the subscriber base and not the overall quality of service. So, they have catchy advertisements and often make false declarations to attract customers to their network, but they do not have infrastructure to satisfy customer demands. This action resulted in too many subscribers for their network to support.
- Marketing Strategies and Pricing Schemes: This also affects traffic behaviour since this would have increased the number of subscribers on the network [1].

The Nigerian Communication Commission (NCC) had noticed the gap between infrastructure roll-out and subscriber’s growth, a situation that compelled the commission to place a ban on promotion in year 2007 and 2008. However, in the year 2009 it rescinded ban, but went into monthly of call quality across the various network[6].

Bandwidth -a measure of the width of a range of frequencies, measured in Hertz (Hz)[4].The bandwidth for the GSM accommodation is 25MHz. The frequency band used for GSM uplink path, that is mobile to base station is 890MHz -915MHz and for GSM downlink path, that is base station to mobile is 935MHz-960MHz [6] .As a result the growing population of people using GSM, the Bandwidth is begging for expansion.

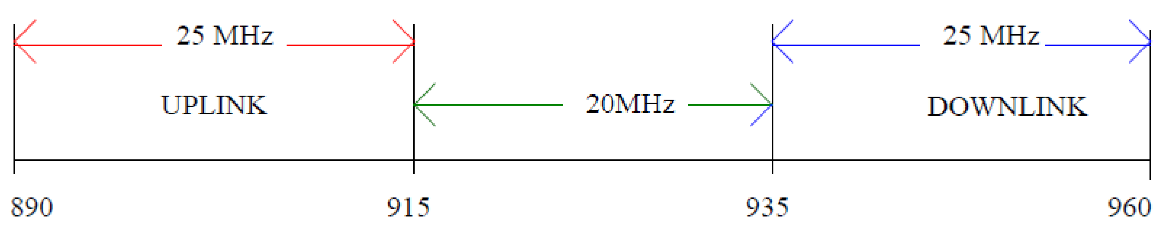

Figure 1: The Uplink and Downlink Bandwidth for GSM [6].

2. ANALYTICAL EXPLANATION OF THE FILTER

Low Pass Filter (LPF): It only attenuates low frequency signals from zero hertz to its cut-off frequency f_c point to pass while blocking those of high frequency signals

A typical **LPF**has a transfer function of

$$H(jw) = \frac{1}{1+jwRC} \quad (1)$$

This can be transformed to the s- plane as

$$H(S) = \frac{1}{1+SRC} \quad (2)$$

2.1 Low-pass to band-pass (LP-BP) transformation and bilinear transformation

Passive band pass are derived from the normalised model. The model is normalised for pass band that extends from frequency and is terminated within load resistance. The low pass model is scaled for the desired cut-off frequency which is transformed into a band pass filter.

Let w_0 represents the centre frequency of the pass band filter.

$$S \rightarrow (s - jw_0)(s + jw_0) \quad (3)$$

Applying the LP – BP transformation, (replacement of the Laplace domain S in the low- pass filter H(s) by Substituting $s \rightarrow (s - jw_0)(s + jw_0)$ in equation (3)

This is to move the poles up to jw_0in the low pass filter since any circuit built with real elements must have all complex poles and zeros in complex conjugate pairs.

Substituting equation 3 into equation 2

$$H(S) = \frac{1}{1+(s - jw_0)(s + jw_0)RC} \quad (4)$$

$$H(S) = \frac{RC(s^2 - w_0^2)}{2(s^2R^2w_0^2C^2)} \quad (5)$$

At higher frequencies of operation, This assumption $R^2C^2 = 1$

Therefore $H(S) = \frac{s^2+w_0^2}{2s^2w_0^2}$ (6)

Where equation 5 is the transfer function of the second order LP filter. Hence,

Establishing the transfer function of the second order low pass filter as

$$\frac{2a^2}{s^2 - 2as + 2a^2} \quad (7)$$

$$H(S) = \frac{s^2+w_0^2}{2s^2w_0^2} \approx \frac{2a^2}{s^2 - 2as + 2a^2} \quad (8)$$

where a is the bandwidth

As s tend to $\rightarrow \frac{s^2+w_0^2}{2s^2w_0^2}$ (9)

Applying the band- pass transformation ,the transfer function H(S) becomes,

$$H(S) = \frac{8a^2S^2}{(S^2+\omega_0^2)(S^2+\omega_0^2) - 4as(S^2+\omega_0^2) + 8a^2S^2} \quad (10)$$

Expanding the denominator on equation (10), gives

$$H(S) = \frac{8a^2s^2}{s^4+2s^2{\omega_o}^2+\omega_o^4-4as^3-4as\omega_o^2+8a^2s^2} \quad (11)$$

Transforming H(S) in equation (11) back to time domain, where s = jω

$$H(t) = \frac{8a^2(j\omega)^2}{(j\omega)^4+2(j\omega)^2{\omega_o}^2+\omega_o^4-4a(j\omega)^3-4a\omega_o^2+8a^2(j\omega)^2} \quad (12)$$

Equation (12) is the analytical transfer function of the passive BP filter.

3. Result

The result is gotten using multi-paradigm numerical computing environment known as MATLAB. A proprietary programming language developed by Math Works, which allows matrix manipulations, plotting of functions and data, implementation.

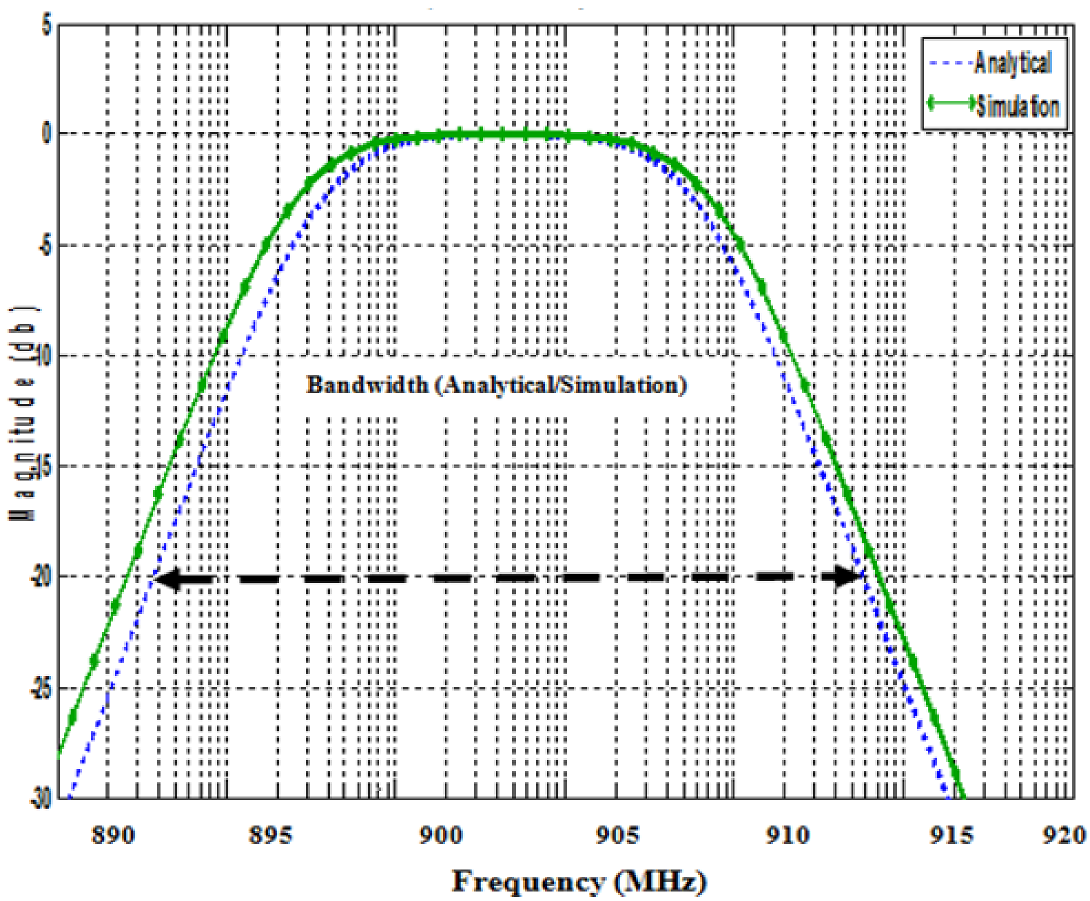

Figure 2: Comparison of Analytical and Simulated Bode plot showing Frequency Bandwidth in term of Magnitude at decibels.The difference between the analytical and simulated harmonic distortion can be seen to be approximately of the range 0.4MHz - 0.5MHz . In practice, this variation is acceptable since it falls within the accepted range of ±5 percent.

4. Discussion

Comparing Q and D Factor , using Analytical frequency X_1

Low cut off frequency f_{1A} = 891MHz

High cut off frequency f_{2A} = 912MHz

Centre frequency $f_{0A} = \frac{f_{1A}+f_{2A}}{2}$

GSJ: Volume 9, Issue 5, May 2021
ISSN 2320-9186

$f_{0A} = (\frac{891+912}{2})$ MHz

$f_{0A} =$ 901.5 MHz

Bandwidth of the filter BW = $f_{2A} - f_{1A}$

BW = (912 - 891) MHz = 21 MHz

The quality factor of the filter Q.F can calculated as :

$Q.F = \frac{f_{0A}}{BW} = \frac{(901.5)\ MHz}{(21)MHz}$

Q.F = 42.93

Dissipation factor D.F $= \frac{1}{Q} = \frac{1}{42.93} = 0.023$

The Bandwidth of the filter is 10 % less than the centre frequencyf_{0A} in 901.5MHz. It is therefore classified as a wide band-pass filter.It has a high level of selectivity, Selectivity is the ability of a filter to pass a selected frequency and reject all other frequencies.At Q.F = 42.93, the quality of the signal strength is high due to it greater number of Q.F and the less D.F, it is under damped.

using Simulation frequency X_2

Low cut off frequency f_{1S} = 890.5MHz

High cut off frequency f_{2S} = 913MHz

Centre frequency $f_{0S} = (\frac{890.5+913}{2})$ MHz

$f_{0S} = (\frac{1803.5}{2})$ MHz

$f_{0S} =$ 901.75 MHz

Bandwidth of the filter BW = $f_{2S} - f_{1S}$

BW = (913 – 890.5) MHz = 22.5 MHz

The quality factor of the filter Q.F $= \frac{f_{0S}}{BW} = \frac{(901.75)\ MHz}{(22.5)MHz}$

Q.F = 40.1

Dissipation factor D.F $= \frac{1}{Q} = \frac{1}{40.1} = 0.024$

The Bandwidth ofthe filter is 10 percent less than the centre frequency f_{0S} in 901.75MHz. It is therefore classified as a wide band-pass filter.It has high level of selectivity.At Q.F = 40.1, the quality of the Signal strength is medium , and the D.F is under damped.

using cellular mobile phone frequency X_3

For the cellular mobile phone frequency bandwidth 890 MHz - 915 MHz

Centre frequency $f_{0GSM} = (\frac{890+915}{2})$ MHz

$f_{0GSM} = (\frac{1805}{2})$ MHz

$f_{0GSM} =$ 903 MHz

Bandwidth of the filter BW = (915-890) MHz = 25 MHz

The quality factor of the filter Q.F $= \frac{f_{0GSM}}{BW} = \frac{(903)\ MHz}{(25\ )MHz}$

Q.F = 36.12

Dissipation factor D.F $= \frac{1}{Q} = \frac{1}{36.12} = 0.028 \cong 0.03$

The Bandwidth of the filter used is 10 % less than the centre frequency f_{0GSM} in 903MHz. It is therefore classified as a wide band-pass filter and it is exposed to harmonics distortion due to the low number Q.F . It has low level of selectivity due to interference. At Q.F = 36.12 the quality of the Signal strength is low than analytical and Simulation and the dissipation factor is over damped.

Table 1: Comparison of the Bode Plot results for the Analytical, Simulated and Cellular mobile phone

S/N	Parameter	Analytical **(891 – 912) MHz**	Simulation **(890.5 – 913) MHz**	Cellular mobile phone (Existing) **(890 – 915) MHz**
1.	Cut-off frequency	It is 10% less than the centre frequency	It is 10% less than the centre frequency	It is 10% less than the centre frequency
2.	Bandwidth	Wide-band pass	Wide-band pass	Wide –band pass
3.	Q- factor	a.High rate of selectivity in term of frequency b.Quening system will be fast	High rate of selectivity in term of frequency b.Quening system will be fast	High rate of selectivity in frequency system b.Quening system will be slow
4.	Signal Strength	High	Medium	Low
5.	Dissipation factor	Under damped Q = 0.02 – 0.024	Under damped Q = 0.02 – 0.024	Over damped Q = 0.03 – 0.034

5. Conclusion

From Table1, the Bode plot of the Simulation and Analytical results show that the higher the quality factor and smaller the dissipation factor, the better the filter. Hence at this point the harmonic distortion is reduced or eliminated.

From Table1, the analyses so far have suggested that the various network service providers (NSP) should sychronised their Global System for Mobile (GSM) dissipation factor to the range of 0.02 – 0.024 in the system to have a reduced distortion on the signal line. It is also necessary for GSM operators to have adequate clearance (considerable Base Station height), Expand their

Bandwidth to accommodate reasonable number of subscribers, GSM Operators should employ more skillful personnel to maintain and address technical problems that occur on frequent basis.

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