Original Research Article

Interference Cancellation by Regenerated Signals in Cellular Network System

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Abstract

Interference reduces the signal quality of any cellular network system and is a major problem in Radio Access Network that need to be addressed because its causes degradation of the signal quality thereby reducing the quality of service of the particular network service provider. Hence, interference must be controlled and managed in other to improve the quality of signal in the cellular network system. This research presents a method of interference reduction by canceling interference by regenerated signals from a cellular network by analyzing the network data from the network statistics using the Microsoft Excel tool. This technique regenerates demodulated uplink data signals for High Speed Uplink Packet Access capable User Equipment and cancels interference by the regenerated signals. This technique will reduce the Multiple Access Interference, improves demodulation performance and increase the uplink system capacity in Wideband Code Division Multiple Access (WCDMA) of the cellular network system.

Keywords: Interference, Cellular Network, Uplink, Signal, Demodulation

Acronym	Meaning
1xRTT	Single Carrier Radio Transmission Technology
AMPS	Advanced Mobile Phone System
AMR	Adoptive MultiRate
AuC	Authentication Centre
BSC	base station controller
BTS	base transceiver station
CDMA	Code Division Multiple Access
CODEC	Coding/Decoding
CS	Circuit Switched
DAMPS	Digital Advanced Mobile Phone Service
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
E_AGCH	E-DCH Absolute Grant Channel
E_DPCCH	E-DCH Dedicated Physical Control Channel
E_DPDCH	E-DCH Dedicated Physical Data Channel
E_RGCH	E-DCH Relative Grant Channel
E-DCH	Enhanced Dedicated Channel
EDGE	Enhanced Data rates for GSM Evolution
E-HICH	E-DCH Hybrid ARQ Indicator Channel

EIR	Equipment Identity Register
EPC	Evolved Packet Core network
EVDO	Evolution-Data Optimized
GGSN	Gateway GPRS Service Node
GPRS	General Packet Radio System
GSM	Global System for Mobile Communications
HLR	Home Location Register
HSDPA	High Speed Downlink Packet Access
HSDPA UE	High Speed Downlink Packet Access User Equipment
HSDPCCH	High Speed Downlink Packet Access Dedicated Physical Control Channel
HSPDSCH	High-Speed Physical DL Shared Channels
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
HSUPA UE	High Speed Uplink Packet Access User Equipment
IMS	IP Multimedia Subsystem
KPI	Key Performance indicators
LTE	Long Term Evolution
MGW	Media Gateway
MME	Mobility Management Entity
MSC	Mobile Switching Center
NMT	Nordic Mobile Telephone
PDC	personal digital cellular
P-GW	PDN-Gateway
PLMN	Public Land Mobile Network
PS	Packet Switched
PSTN	Public Switched Telephone Network
QoS	Quality of Service
R99 UE	Release 99 User Equipment
RNC	Radio Network Controller
RTWP	Receive Total Wideband Power
SGSN	Serving GPRS Service Node
S-GW	Signaling Gateway
SMSC	Short Message service center
TACS	Total Access Communication System
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access (TD-SCDMA)
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
VLR	Visitor Location Register
WBSS	Wireless Base Station Subsystem
WCDMA	Wide-band Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access

CSSR	Call setup success rate

1.0 Introduction

Mobile telecommunication industries in Nigeria have undergone significant changes and great improvements over the past few decades. However, there have been some limitations to the development of the cellular network system not only in Nigeria but also in some part of the World especially in developing Countries [1, 2].

In cellular network system, it is however difficult to manage the medium of transmission because of interference waves and noise problems that are not easy to mitigate. Interference which is anything that modifies or disrupts a signal as it travels along a channel between a source and a receiver; the term typically refers to the addition of unwanted signals to a useful signal and which is the sum of all signal contributions that are neither noise nor the wanted signal is a fundamental limiting factor in the performance of cellular network systems. In cellular networks, interference is one of the most common problems in the Radio Access Network (RAN). It is a serious challenge for wireless systems, this is one the main reason why there has been a great attention to the reduction of interference effects on cellular network systems in order to procure sufficient and better quality of service (QoS) for the subscribers [1, 3].

Interference is generated by different factors such as thermal noise, intra cell traffic, traffic in adjacent cells and external traffic. In addition, the increase in number of users in a cell subsequently increases the total interference in the network. Hence, interference must be controlled and manage in other to improve the rate at which data is processed and transferred through the network system. During the initial development of cellular network systems, the Global System of Mobile Communication (GSM) which is the second generation (2G) cellular phones generates much interference. Though, the interference from the third generation (3G) cellular phones is considerably lower than the ones from the 2G phones [1, 2]. Interference can cause degradation of signal quality thereby reducing the QoS of the particular network service provider. Some causes and sources of interference are:

i. Another mobile in the same cell
ii. A call in progress in the neighboring cell
iii. Other base stations operating on the same frequency
iv. Any non-cellular system which leaks energy into the cellular frequency band

(i) and (ii) are the ones prominent with WCDMA. Moreover, even if different wireless services do not generate harmonics, frequency drifts, or Radio Frequency (RF) leakage, cell sites are subject to internal interference caused by the improper conductivity of passive devices such as connectors, cables, or antennas. This internal interference can generate inter-modulation signals at the same frequency band as mobile transmitters (uplink). Another common case of interference internal to the RAN is caused by frequency re-farming. Network service providers evolving their mobile technology to LTE use refarming to deliver higher throughput for mobile devices while maintaining their existing technologies such as GSM and WCDMA. This technique supports a gradual adoption of LTE. The co-existence of multiple technologies in a limited spectrum is forcing mobile operators to increase the number of carriers and to re-use frequencies, creating a RAN subject to internal interference. Inter-modulation in passive components is created when two signals are transmitted in a cabling system with improper conductivity characteristics such as loose jumpers, bent cables, different metals in jumpers, or corrosion. This inter-modulation generates signals as products or multiples of the two transmitted signals [4, 5, 6]

2.0 Wideband Code Division Multiple Access (WCDMA)

Wideband Code Division Multiple Access (WCDMA) is a 3G technology which increases data transmission rates through the Code Division Multiplexing (CDM) air interface rather than the Time Division Multiplexing (TDM) air interface of Global System of Mobile Communication (GSM) systems. It supports very high speed multimedia services such as full motion video, internet access and video conferencing. It can also easily handle bandwidth intensive applications such as data and image transmission via the Internet. WCDMA is a direct spread technology it spreads its transmissions over a wide range, 5MHz carrier and can carry both voice and data simultaneously via a technique termed Multi-Rab technology. It features a peak data rate of 384 kbps with peak network downlink speed of 2 Mbps and average user throughput of 220- 320 kbps. WCDMA boasts increased capacity over EDGE for high bandwidth applications and features which include; enhanced security, quality of service, multimedia support and reduced latency. It works with fiber based wireless access using radio over fiber (RoF) technology. Access schemes effectively combine the high capacity of optical fiber with the flexibility of wireless networks. WCDMA RoF systems have an impact not only on multiple-user interference but also on inter-modulation distortion and clipping noise power.

WCDMA or the family of Universal Mobile Telecommunications System (UMTS) along with UMTSFDD, UTRA-FDD or IMT-2000 CDMA Direct Spread are air interface standard found in 3G mobile telecommunications networks that is being developed as WCDMA. Unlike GSM and GPRS which rely on the use of the TDMA protocol, WCDMA which is like CDMA allows all users to transmit at the same time and to share the same RF carrier. Each mobile user's call is uniquely differentiated from other calls by a set of specialized codes added to the transmission [5].

With CDMA technology, interference is a critical factor because communications occur on the same frequency band and time slot such as in the UMTS FDD mode. On the one hand, it is directly linked to coverage and capacity of such a network. So, understanding the relationship between coverage and capacity and how it is affected by interference and transmit power is essential for UMTS network planning. The interference level is directly related to the user's density in the considered cell and its neighbors and affects both the cell range and the capacity of the system. The higher the number of users in the system, the higher the interference and the smaller the cell range. The causes of interference are diverse. Radio Frequency (RF) interference to mobile communication network may be caused by such parameters as an original dedicated radio system occupying an existing frequency resource, improper network configuration by different operators (value of power), cell overlapping, the radio channel, electromagnetic compatibility (EMC), external interference sources. The primary forms of interference to mobile communication systems mainly include: common-frequency interference, adjacent-frequency interference, out of band spurious emission, inter-modulation emission, and blocking interference. The problem of interference between systems working in different frequencies is caused by hardware problem in the transmitter (Tx) and the receiver (Rx). Also the interference between the Tx and the Rx depends on some parameters such as the interval between the working frequency ranges of the two systems and the spatial distance which separate the Tx and Rx. For a WCDMA system, the interference can be generated by different sources, namely, thermal noise, traffic intra-cell, traffic in adjacent cells and external traffic [2, 7].

3.0 High Speed Uplink Packet Access (HSUPA)

In Release 5, HSDPA technology was introduced. This greatly increased downlink transmission rate. In order to meet the rapidly growing demands for data services in the uplink, 3GPP Release 6 introduced HSUPA. The technical advancements in HSUPA include fast scheduling, fast hybrid automatic repeat request (HARQ), shorter transmission time interval (TTI), and macro diversity combining (MDC). Benefits of HSUPA were improvement in the uplink capacity, increase in user data rate, and reduction in the transmission delay on the WCDMA network.

HSUPA has the following impacts on the network:

i. A new control channel that requires more power in the uplink, called E-DPCCH.
ii. When the uplink load is limited and there is a large number of UEs, the UEs can upload data only at a guaranteed bit rate (GBR), for example, 64 kbit/s. As compared with R99 channels, E-DPCCH consumes more system resources.

3.1 HSUPA Channels

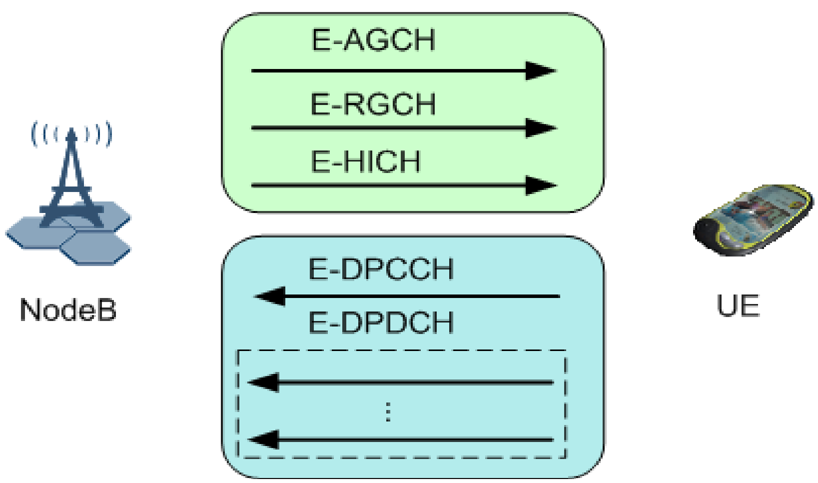

Figure 1: HSUPA Physical Channels

The enhanced dedicated channel (E-DCH) has a TTI of either 10 ms or 2 ms. It is mapped onto the E-DPDCH or E-DPCCH. When the TTI is 10 ms, the E-DCH provides better uplink coverage performance; when the TTI is 2 ms, the E-DCH provides higher transmission rates.

The E-DPDCH carries data in the uplink. The spreading factor of the E-DPDCH varies from SF256 to SF2 depending on the data transmission rate.

The E-DPCCH carries control information related to data transmission in the uplink. The control information consists of the E-DCH transport format combination indicator (E-TFCI), retransmission sequence number (RSN), and happy bit. The SF of the E-DPCCH is fixed to 256.

To implement the HARQ function, the E-HICH is introduced in the downlink. The E-HICH carries retransmission requests from the Node B. The SF of the E-HICH is fixed to 128.

The downlink E-AGCH and E-RGCH carry the HSUPA scheduling control information. The E-AGCH is a shared channel, which carries the maximum E-DPDCH to DPCCH power ratio, that is, absolute grants. The SF of the E-AGCH is fixed to 256.

The E-RGCH is a dedicated channel, which is used to indicate relative grants and increase or decrease the maximum E-DPDCH to DPCCH power ratio. The SF of the E-RGCH is fixed to 128 [4].

4.0 Methodology

As stated earlier, interference in WCDMA is generated by different attributes such as thermal noise, intra cell traffic, traffic in adjacent cells and external traffic. Therefore, the use of regenerated signal from the network statistics as a suitable technique to mitigate and possibly cancel the interference was employed in this work because this strategy reduces the Multiple Access Interference (MAI), improves demodulation performance and increases the uplink system capacity. The network statistics was analyzed using Microsoft Excel tool. Interference cancellation procedures and objectives are as itemized beneath:

(i) The network detects E-DPDCH signals from HSUPA User's Equipments (UEs).

(ii) The network regenerates signals of UEs on their respective E-DPDCHs by using the detection results and channel estimation results.

(iii) The regenerated signals are then removed from the received signals and demodulated.

(iv) The network demodulates and decodes the baseband signals with interference canceled.

4.0 Discussion of Results

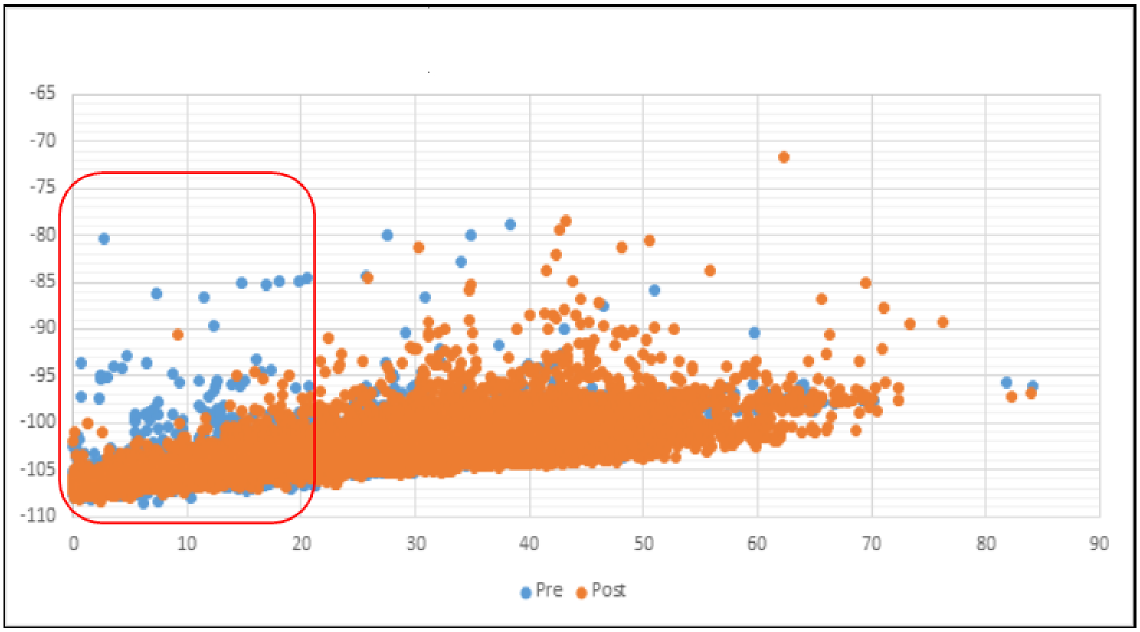

Figure 2: Number of DCH UE's as Compared to UL Load of Different Cells

It can be seen from Figure 2 chart showing DCH User Number versus RTWP trend that post RTWP samples have shifted to lower values particularly on cells with DCH UE numbers less than 20. This is a great achievement as for cells with lower user numbers, whose experience was supposedly very poor as result of high RTWP was greatly improved.

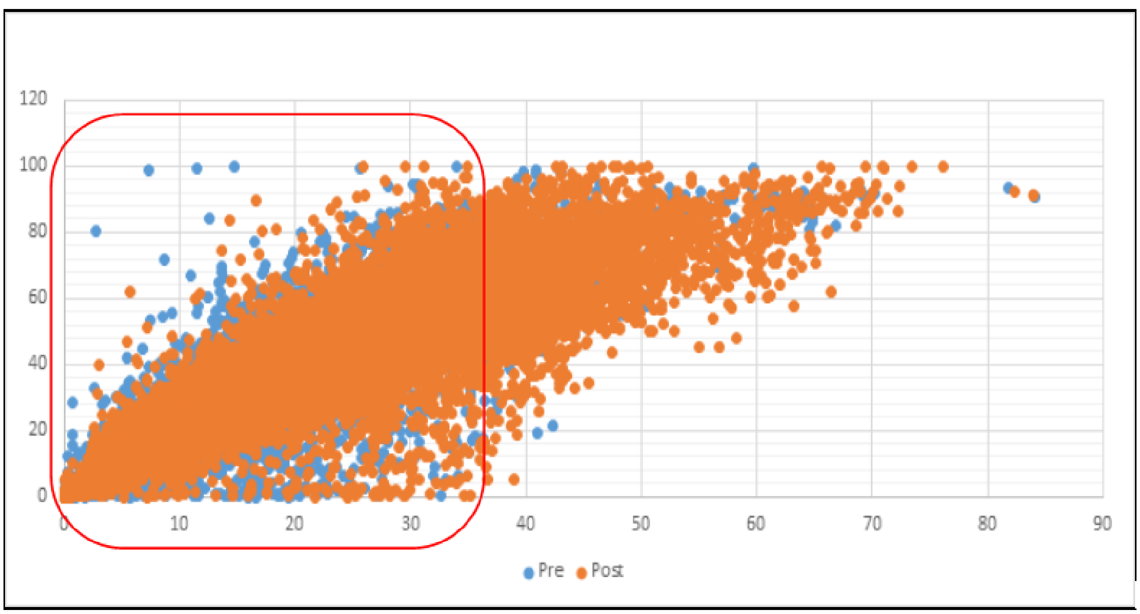

Figure 3: Mean UL Power Load as Compared to Number of DCH UE's in a Cell

From figure 3, while PS and CS traffic trend was stable, uplink load has reduced as can be seen from the comparison of Number of DCH UEs and uplink load factor, especially as the DCH User number approaches a hallmark of 35 users. This implies an increased capacity as more users can camp on these cells with minimal impact on the loading factor of the cells.

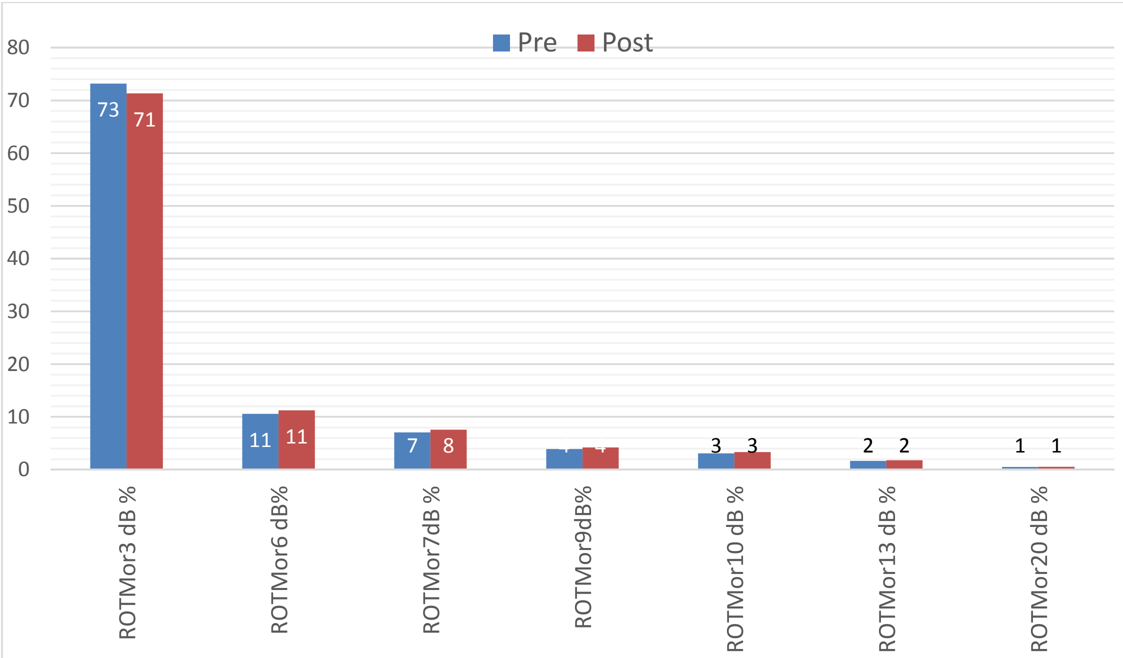

Figure 4: Number of TTIs in which HSUPA Users have Data to Transmit under Different Uu Interface Loads in a Cell (X=3, 6, 7, 9, 10, 13, 20)

From figure 4 chart it can be seen that the percentage share of each bins corresponding to different load ranges in the air interface. Although percentage share of 3dB load range is lower in the post as compared to the pre implementation value, it still had more samples in the post as compared to pre and due to more samples even in the other load ranges. 3dB range is more impacted by this study.

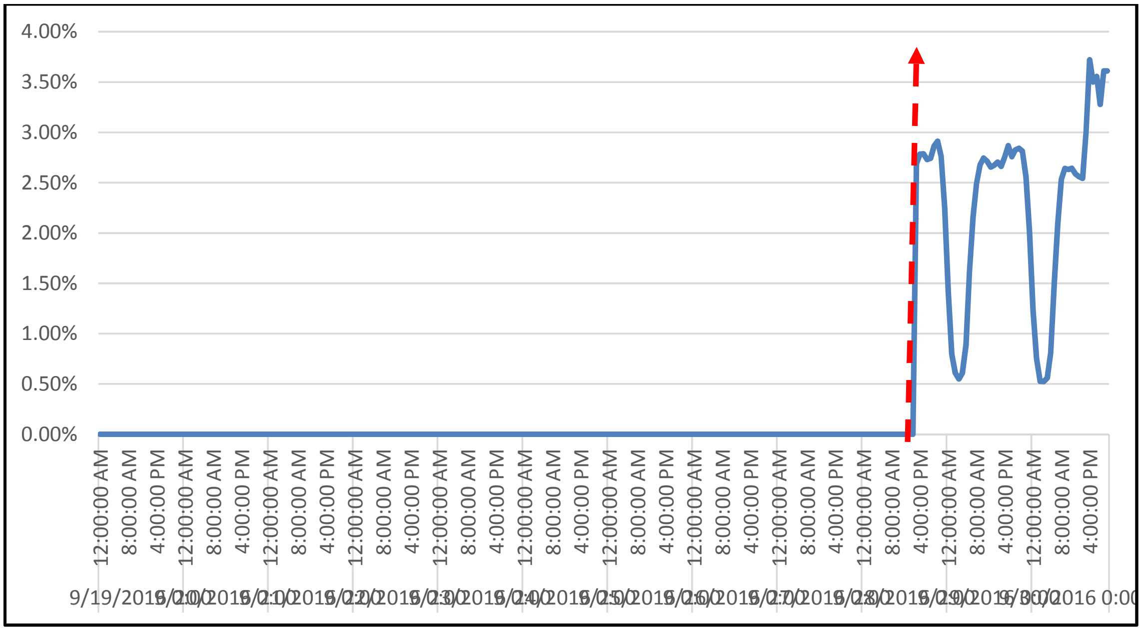

Figure 5: Mean Interference Cancellation Efficiency (%)

From figure 5, the mean interference efficiency improved from 0% to about 3%. This measures the effectiveness of this technique and the gains from using this technique in UMTS HSUPA interference mitigation**.**

5.0 Conclusion and Recommendations

From the results of our analysis we have been able to propose an interference reduction and cancellation technique in WCDMA using the regenerated signals in this research work to cancel the Uplink interference in HSUPA capable UEs.

Hence, by using the regenerated signals technique of Uplink interference cancellation, we have demonstrated the efficiency of this technique through the simulated results. This technique absolutely cancels interference. In addition, it considerably increases the mean cell capacity and average quality of the cellular network system.

It is therefore recommended that cellular network service providers should adapt this strategy in mitigating interference in WCDMA in other to implore and optimize the quality of service generally.

6.0 References

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