The 2004 IEEE Asia-Pacific Conference on
Circuits and Systems, December 6-9, 2004

HANDOVER CONSIDERATIONS IN VCO DESIGN FOR MULTISTANDARD WIRELESS RECEIVER

V. Vibhute, R. Veljanovski, J. Singh, A. Zayegh, A. Stojcevski

Center of Telecommunications and Microelectronics
Victoria University, Melbourne, Australia
Email: vidya@ee.vu.edu.au

ABSTRACT

This paper analyses handover scenario used in 3G standard and results are used to design and implement a reconfigurable voltage controlled oscillator (VCO) for multistandard wireless receiver. The third-generation (3G) standard has introduced hybrid wireless network for better use of resources. The typical example of hybrid network is integration of radio access technologies such as Wideband Code-Division Multiple-Access (W-CDMA) and Global System for Mobile (GSM). In such hybrid systems handover analysis is mainly used to extract general requirements and specifications for front-end design. In 3G different handover types are used such as 3G to 3G, 2G to 3G and 3G to 2G, to provide better service to users. The static handover analysis is performed to support design and implementation of a reconfigurable, compact, multi-standard compatible VCO based on switch architecture.

1. INTRODUCTION

The explosive growth of data transfer in wireless communication has produced an imperative need for large capacity and more efficient wireless systems. The large capacity and range of new applications are the driving force for development of 3G standard. The 3G standard [1] has introduced a system architecture based on multiple technologies, generally referred as hybrid wireless network, for better use of resources. In the early phases of 3G-standardisation W-CDMA and GSM radio access technologies are included; in later stages other technologies will also be considered and included. Some of the aims of using multiple radio access technologies are to provide better quality of service and traffic management.

The handover is the most important aspect of modern personal communication systems, used to provide access to different network technologies and multiple cells. In 3G, different types of handovers are used, which needs to be considered for designing a multistandard wireless receiver. The handover operation is performed based on signal measurements at discrete frequencies; so multistandard receiver architecture must provide the interface to multiple frequencies.

The major challenges in developing such multistandard compatible devices are to limit the additional hardware and reuse maximum number of building blocks for the multiple modes of operation. To add a multistandard feature to single receiver architecture, the receiver building blocks need to be capable of handling and generating different frequency bands. The VCO is one of the important functional blocks of a multistandard receiver used to up and down convert signals, therefore, very stringent requirements are placed on spectral purity of the local oscillators. There has been numerous attempts to integrate on-chip VCOs using different technologies. Among these implementations Complementary Metal Oxide Semiconductor (CMOS) VCOs have attracted the most attention due to the possibility of combining radio frequency (RF) front end with baseband electronics.

In this paper the design and implementation of a reconfigurable VCO for multistandard receivers is presented. The paper is organised as follows, in section 2, 3G-handover types and scenario is presented, followed by the multistandard receiver architecture in section 3. Section 4 presents the reconfigurable VCO design and implementation. Experimental results are presented in section 5 and finally the conclusions are drawn in section 6.

2. HANDOVER IN 3G NETWORKS

The major aspect of modern personal communication systems is mobility, and it is frequently considered as the main advantage of new wireless systems. It offers freedom to be able to make and receive calls anywhere, at any time, creating a totally new dimension in modern communications. To achieve this mobility one of the most important concepts used is handover. It makes it possible for a user to travel from one area to another while having a seamless connection. The basic operation of handover is dynamic change in serving base station based on the quality of the link between the base station and the mobile terminal. The whole process of handover can be summarised as removing an existing connection and replacing it by a new connection in the new cell (target cell).

The measurement report of link quality of the connection with different base stations is periodically performed and transferred to a network controller, where the decision regarding handover is taken and executed. The decision of handover is based on link quality measurements and also the resources available in the target cell. The inability to execute a complete handover procedure and establish a new connection in the target cell is referred to as a handover failure. The handover request to a target cell is similar to an incoming call and optimisation of the resource utilisation is very important to minimise call blocking and call dropping probabilities.

In 3G, to provide load control, coverage provisioning and quality of services different types of handover are used. They are generally classified as hard, intersystem and soft handovers.

2.1 Hard Handover

In hard handover, the connection between mobile terminal also referred as user equipment (UE) and radio access network is broken and a new radio connection is established. This type of handover is similar to handover used in GSM cellular system. The algorithm used for this handover is fairly simple. In this algorithm the mobile station performs a handover when the signal strength of a target cell exceeds the signal strength of the current cell with a given threshold. In 3G hard handovers are used to change the frequency band and change the cell in the same frequency band.

In the frequency allocation process for 3G, each operator can claim additional spectrum to enhance the capacity. In this situation, the service provider will operate in several bands of approximately 5MHz, resulting in the need for handovers between one-frequency band to another. The typical frequency bands and the UE handover situation is as shown in Figure 1(a). When the UE enters target cell area the power received from old base station gradually reduces, thus for service inter frequency hard handover is performed and UE is connected to target base station.

The hard handover algorithms are simple in operation. However, some times high blocking probabilities are experienced by handover users entering a new cell. This probability can be reduced by giving priority to handover users over new users. This results in less efficient use of the capacity and higher blocking probabilities for new users.

2.2 Inter-system Handover

Intersystem handovers are important to support co-existence of different radio access technology architectures. In the initial stages of deployment of 3G networks, the rural areas are not covered by the WCDMA network. Thus, the existing 2G network such as GSM is used to provide service to users. On the other hand the additional capacity provided by the WCDMA network will be used to unburden the urban GSM network. The inter-system handover in 3G systems will be in WCDMA and GSM or frequency division duplex (FDD) and time division duplex (TDD) operating modes. The typical WCDMA and GSM cell and handover situation is as shown in Figure 1(b). When the UE enters new cell area the power received from old base station gradually reduces, thus for service inter- system handover is performed and UE is connected to the new base station with different technology.

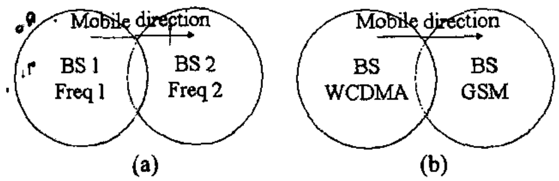

Figure 1(a) Inter-frequency handover, (b) Inter-system handover

2.3 Soft Handover

Soft handover is a Code-Division Multiple-Access (CDMA) specific handover type implemented in the 3G network. A soft handover occurs when the mobile station is in the overlapping coverage area of two adjacent cells. The user has two simultaneous connections to the network using different air interface channels concurrently. The soft handover is used for 3G to 3G handovers to reduce interference and implement frequency reuse.

2.4. Static Handover Model

A static handover model is used to simulate the handovers in 3G network. The handover required in three 3G-cell structures will be based totally on the received power at mobile receiver. The 3G cells are organised as shown in Figure 2, the mobile starting point, direction and distance are randomly selected. Macro cell propagation model [1] is used for path loss calculations, as it is applicable for the test scenarios in urban and suburban areas outside the high rise core. The simplified path loss equation for 3G macro cell propagation model is given by equation (1):

$$L = 128.1 + 37.6 \log_{10}(R) \qquad (1)$$

Where L is path loss, R is the base station - UE separation in kilometers.

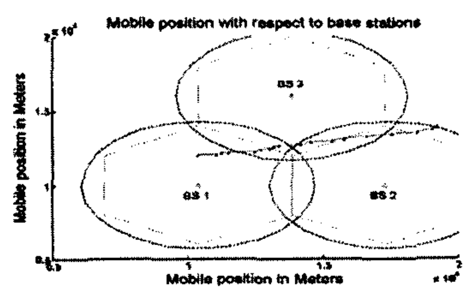

Figure 2. Position and coverage of 3 base stations

The received pilot signal power at UE is given by equation (2) as follows:

$$Rx = 10\log_{10}\left(\frac{10^{pilot/10}}{10^{L/10}}\right) \qquad (2)$$

Where Rx is received power at UE and *pilot* is received pilot signal power.

The received pilot power at mobile from different base stations is directly proportional to distance as shown in Figure 3.

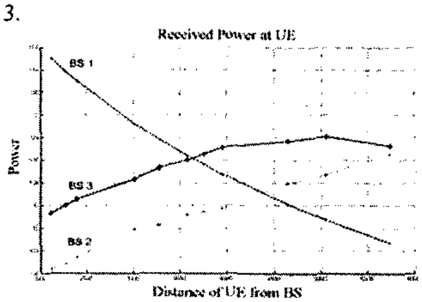

Figure 3. Received power at UE from base stations

In addition to three 3G-cell analysis a static probability analysis of requiring handoff is carried on a single 3G cell. The random parameters used are UE initiates a call in 4 km cell, vehicular speed is selected between 8 and 96km/hr and direction is selected to be between 0 and 360 $^{0.}$

In the probability analysis the chance of reaching the cell boundary is dependent on the call holding time. Cumulative distribution function graph and its summary for requiring handover to another cell are as shown in Figure 4 and Table 1 respectively. The static probability handover analysis indicates that the handover are integral part of 3G systems and the handover decisions are performed on signal power measurement results. For example if user is using call for 5 minutes there is a 40% chance of handover.

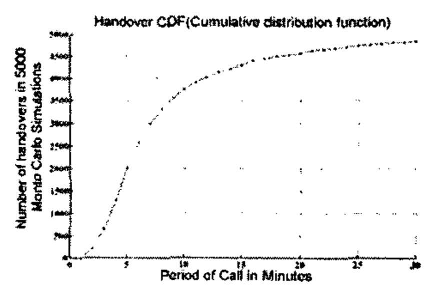

Figure 4. Probability of handover in single cell

Within 3G systems, the soft handover is used in order to minimise the interference in neighbouring base stations and to allow the use of identical carrier frequencies. So a single wireless receiver will be sufficient to perform the required measurements.

Table 1. Handover Probability

Handover Probability, %	Call time in Minutes
12	3
40	5
75	10
85	15

However, to perform inter-frequency, inter-mode and inter-system handovers multiple frequency bands are involved which forces the use of a multistandard wireless receiver. In this paper only inter-system handovers are taken in to considerations, however similar approach can be used to include other handovers.

When a UE moves between base-stations the handover is handled by network with assistance from the UE unit. The multistandard UE continuously monitors base stations. When the network senses the need for a handover, the base station measures some system parameters and commands the UE to measure other parameters and report the results. In addition to this measurement command the base station directs the UE to operate in compressed mode and provides the compressed mode parameters information. The compressed mode is a method of inserting gaps in the signal to allow time for measurement and reporting functions. This insertion gap is provided and used by UE to switch the frequency and perform the measurement. To perform multiple measurements multiple gaps are provided. When a transmission gap is used for GSM measurements any transmission gap pattern sequence can be used which contains transmission gap of lengths 3,4,7,10 or 14 slots. This insertion gap time is decided by the upper layers based on maximum delay for a frequency synthesiser to switch from one frequency to another [1].

When the measurements of base station and UE are analysed and the decision of handover is finalised the base station sends a Handover command to UE. This signal is used to reconfigure the hardware to change the operating frequency for different standard.

3. MULTISTANDARD ARCHITECTURE

Most of the multistandard wireless receiver architectures are based on low intermediate frequency (IF) receiver or direct conversion receiver (DCR) architecture for implementation because of its suitability for portable wireless receivers.

The first approach of multistandard receiver architecture is based on DCR where multiple RF front-ends are used in parallel. This eases the stringent requirements of RF systems design. A typical example of multistandard system architecture is where multiple blocks are required and used for multistandard compatibility. The major disadvantage of this architecture is multiple RF front-end blocks such as RF filter, LNA, mixer and VCO are required.

The second approach of designing multistandard receiver is to design a single receiver architecture for all the standards [2]. However multiple blocks can be shared in which case less on-chip and off-chip components could be used. The design of the LNA, mixer, filter and VCO needs to provide compatibility to all the frequency bands of interest. To add multistandard feature to single wireless receiver architecture, there is a need of multiple frequency generation and frequency band selection for different standards. Multiple frequencies generation is the function of the VCO.

The requirements of multistandard compatible VCO are wide range of frequency generation and reduced phase noise. Estimation of range of frequencies and tuning range can be easily analysed from handover scenarios. The use of reconfigurable VCO in multistandard receiver architecture is as shown in Figure 5.

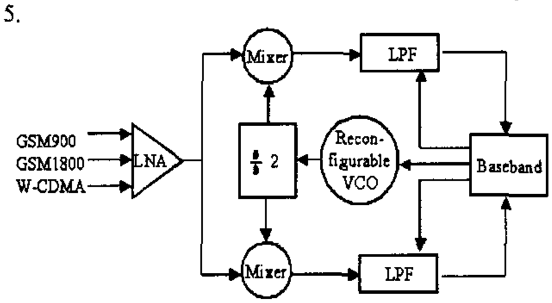

Figure 5. Multistandard receiver architecture with VCO

The reconfigurable VCO is used to generate the frequencies required for multistandard receiver based on a control signal from baseband. The reconfigurability in VCO is used to change combination of components based on input control signal. The control signal is derived from the base station commands to the UE at baseband control logic. The control signal is used to select frequency for measurement in insertion gap or to select frequency for working in specific standard.

4. VOLTAGE CONTROLLED OSCILLATOR

The schematic of the reconfigurable VCO is as shown in Figure 6 [3]. It is the standard symmetrical cross-coupled LC tank VCO, with the additional tail filter. The tail filter is added to improve the phase noise performance by using tail-filtering technique based on [4-5]. The VCO contains switched variable capacitors controlled by switch control signal generated by baseband. The C1, C2 and C3 capacitor network is selected to generate 900MHz, 1.8GHz and 2.1GHz frequencies respectively.

5. VCO SIMULATION RESULTS

The VCO is designed and implemented using Spectre RF tool from Cadence. The switches are considered to be ideal switches without any losses. The tuning range, phase noise and power consumption performance are as shown in Table 2.

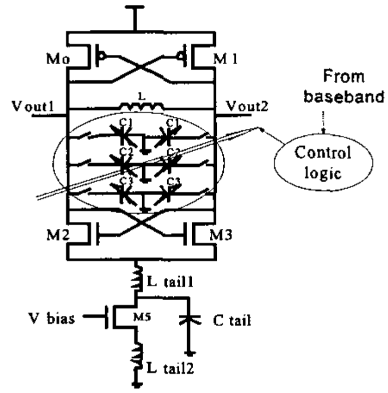

Figure 6: VCO [7]

Table 2. Result Summary

Frequency	Tuning range	Phase noise at 600KHz	Power consumption
1.8GHz	37MHz	-134	131.1
3.6GHz	88MHz	-128	242.91
4.2GHz	116MHz	-127	215

6. CONCLUSION

The review of handover types in 3G is presented, the handover types are used to extract information related to front-end design of a multistandard wireless receiver. The handover simulations are prone to some limitations such as only one cell is considered with single user, model is based on static environment and mathematical model not on measured channel responces. These factors will have an effect on the analysis.

The CMOS multiband reconfigurable VCO suitable to generate wide range of frequencies required for modern wireless systems such as multistandard wireless receiver is designed and implemented. The achieved results are phase noise (<120 at 600KHz) and power consumption (<250 uW).

7. REFERENCES

[1] "3GPPP TR 25.922", 3rd Generation Partnership Project, Dec. 2000.

[2] J. Ryynänen, et al, "A Single-Chip Multimode Receiver for GSM900, DCS1800, PCS1900, and WCDMA", IEEE Journal of Solid-State Circuits, Vol.38, pp.594-602, 2003.

[3] V. Vibhute, D. Fitrio, J. Singh, A. Zayegh, A. Stojcevski, "A Tunable VCO for Multistandard Mobile Receiver", IEEE International Workshop on Electronic Design, Test and Applications, 2004.

[4] J.J. Rael, A.A. Abidi, "Physical Processes of Phase Noise in Differential LC Oscillators," *IEEE Custom Integrated Circuits Conference,* 2000.

[5] E. Hegazi, H. Sjoland, A. Abidi, "A Filtering Technique to Lower Oscillator Phase Noise," *ISSCC of Analog Techniques*, 2001.