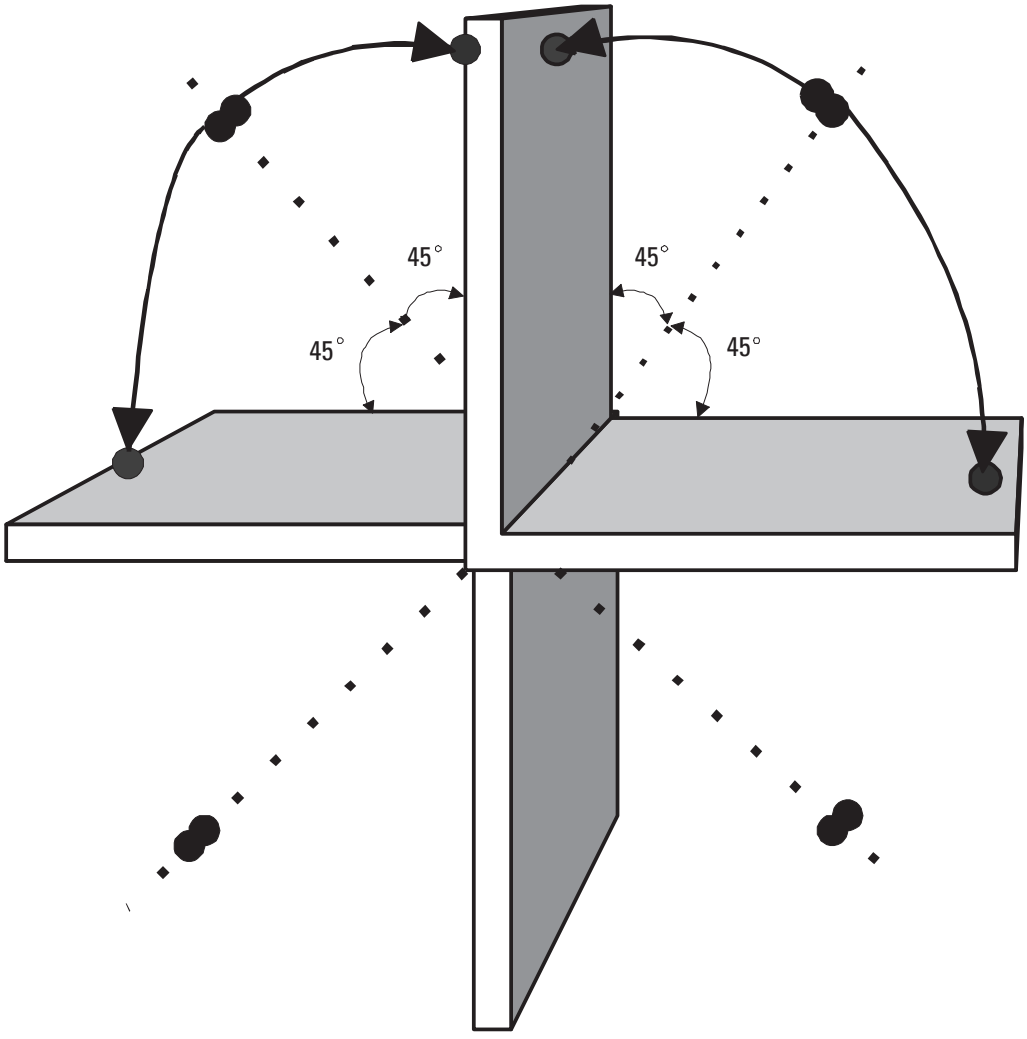
Agilent AN 1335

HPSK Spreading for 3G

Application Note



Agilent Technologies

Innovating the HP Way

Introduction

In mobile communications, battery life is one of the most important characteristics of the handset, and the efficiency of the handset power amplifier is key to maximizing battery life. Amplifiers are typically most efficient when they operate close to their saturation level. Therefore, mobile station amplifiers should ideally be designed so that the average power level of the signal is as close as possible to this saturation level.

This works well for 2G (Second Generation) modulation formats, such as OQPSK (Offset Quadrature Phase Shift Keying) or GMSK (Gaussian Minimum Shift Keying). OQPSK avoids symbol transitions through zero, which reduces the peak-to-average power ratio of the signal. GMSK is a constant-amplitude modulation format, so peak-to-average power ratio is not an issue. For these formats, the headroom required in the amplifier to prevent compression of the signal and interference with the adjacent frequency channels is small (or, in the case of GMSK, nonexistent). Thus, the amplifier can operate more efficiently.

However, in 3G (Third Generation) spread-spectrum systems, such as W-CDMA (3GPP) and cdma2000 (3GPP2)[1], the handset can transmit multiple channels at different amplitude levels. Modulation schemes such as OQPSK or GMSK do not prevent zero-crossings for multiple channels and are no longer suitable. There is a need for a modulation format or a spreading technique that can accommodate multiple channels at different power levels while producing signals with low peak-to-average power ratios.

HPSK (Hybrid Phase Shift Keying), also known as OCQPSK (Orthogonal Complex Quadrature Phase Shift Keying), has been proposed as the spreading technique for W-CDMA and cdma2000. HPSK is a complex spreading scheme that is very different from the modulation formats commonly used until now. The objective of this application note is to provide an overview of HPSK and explain how to start making modulation quality measurements on the reverse link (uplink) of 3G spread-spectrum systems.

This application note starts with the basic structure of the reverse link (uplink) for W-CDMA and cdma2000 with no scrambling, and explains the transition through complex scrambling to HPSK. The block diagrams shown are generic block diagrams for HPSK that are not particular to either W-CDMA or cdma2000.

The application note then describes:

- Why complex scrambling is used and how it works
- Why HPSK is used and how it works

Finally, the application note shows how to measure modulation quality on the reverse link of 3G systems with existing instruments.

Contents

1. Throughout this application note, W-CDMA refers to the 3GPP (Third Generation Partnership Project) proposal for a 3G system, and cdma2000 refers to the 3GPP2 (Third Generation Partnership Project 2) proposal. Both of these proposals are currently under development. Therefore, the information in this application note is subject to change.

1. Basic structure of the reverse link (uplink) of 3G systems

Unlike 2G systems, in 3G systems, such as W-CDMA and cdma2000, the mobile station can transmit more than one channel. The different channels are used for control purposes or to send voice and/or high-speed data.

For example, for W-CDMA the basic uplink signal comprises one Dedicated Physical Data CHannel (DPDCH) and one Dedicated Physical Control CHannel (DPCCH). The DPCCH carries control information, such as an embedded Pilot that allows for synchronous detection. The DPDCH carries voice or data. Optionally, more DPDCHs may be added to support higher data rates.

In the case of cdma2000, the mobile transmits a Reverse Pilot (R-Pilot) channel to allow the base station to perform synchronous detection. Additional channels, such as the Reverse Fundamental CHannel (R-FCH) and Reverse Supplemental CHannels (R-SCHs) are used to send voice and high-speed data, respectively.

Although the names and frame structure of the channels are currently different for W-CDMA and cdma2000, the basic block diagrams of the reverse links (uplinks) are very similar. The block diagrams used in this application note do not exactly correspond to W-CDMA or cdma2000. They are generic block diagrams that explain the evolution of the 3G reverse link structure from basic complex scrambling to HPSK.

For both W-CDMA and cdma2000, the channels are I/Q multiplexed. In the case of transmitting only two channels, one of the channels (DPDCH or R-Pilot) is applied to the I path and the other channel (DPCCH or R-FCH) is applied to the Q path. Additional high data rate channels are combined alternatively on the I or Q paths. Each channel is spread by a different orthogonal code.

The different channels can be at different power levels. If, as shown in Figure 1, no other spreading or scrambling is applied, the I and Q signals are directly filtered and applied to the I/Q modulator. In that scheme, channels with different power levels result in different amplitudes for I and Q, which can produce strange constellations. For example, in the case of only two channels, unequal power levels result in a rectangular 4-QAM constellation. In general, equal distribution of powers between the axes is desired, especially at the receiver. Equal powers allow for symmetry between the I and the Q paths.

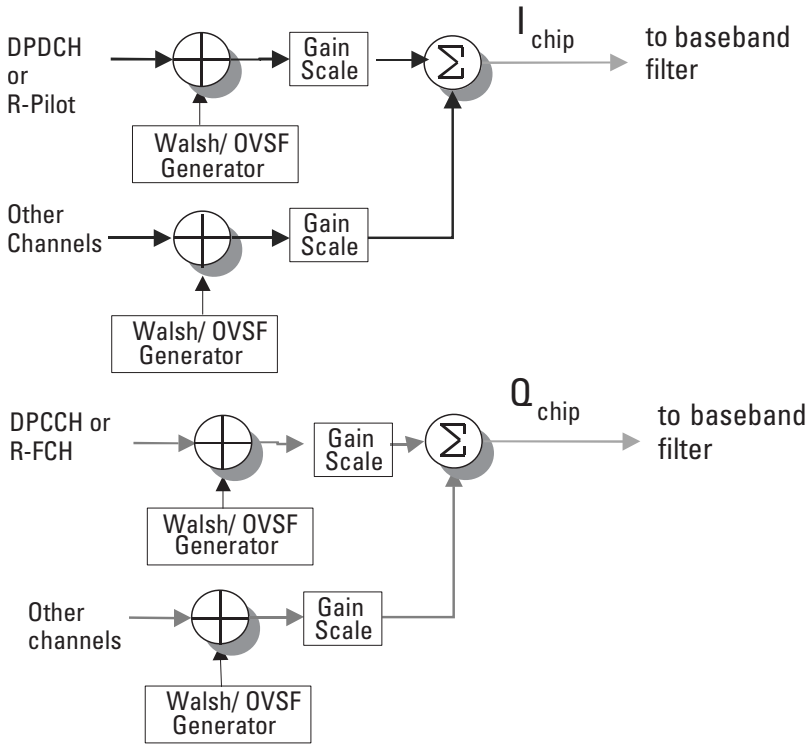


Figure 1. Basic reverse channel structure of 3G systems (W-CDMA and cdma2000) without scrambling

2. Complex scrambling

In the reverse link of cdmaOne systems, both the I and Q signals are scrambled with a PN (Pseudo-Noise) sequence prior to modulation. PN sequences from different users are uncorrelated to each other, which allows the base station to recover the signal from the appropriate user with minimum interference from others.

Instead of traditional scrambling, complex scrambling has been proposed for the reverse link (uplink) of both W-CDMA and cdma2000 systems. In addition to providing differentiation among users, complex scrambling fixes the unequal distribution of powers by continuously rotating the constellation and thereby distributing the power evenly between the axes. Thus, the receiver does not have to deal with different power loads for the I and Q paths.

Figure 2 shows a block diagram of the reverse link (uplink) with basic complex scrambling. After complex scrambling, the resulting I and Q baseband signals are filtered and used to modulate the carrier.

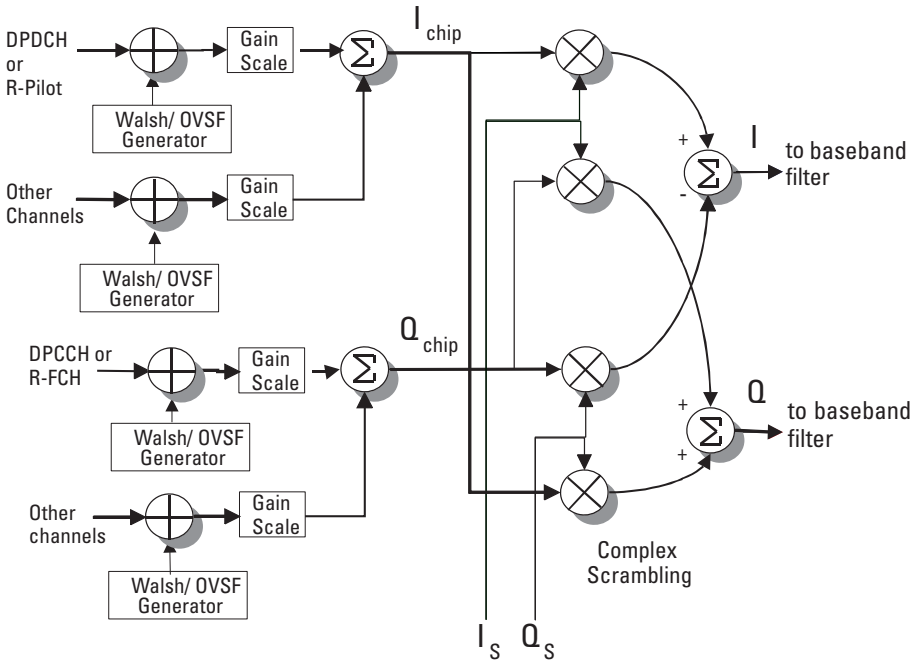


Figure 2. Basic reverse channel structure of 3G systems (W-CDMA and cdma2000) with basic complex scrambling

How does complex scrambling work?

Figure 3 shows the block diagram for complex scrambling. Mathematically, complex scrambling performs the multiplication of two complex signals: the complex data signal, which has already been spread into chips ($I_{chip} + jQ_{chip}$) and the complex scrambling signal ($I_S + jQ_S$). To verify this, derive the expression for the final I and Q signals by following the block diagram:

1. $I = I_{chip} \cdot I_S - Q_{chip} \cdot Q_S$

2. $Q = I_{chip} \cdot Q_S + Q_{chip} \cdot I_S$

The data signal, scrambling signal, and resulting baseband signal are not really complex signals. However, the resulting I and Q signals are later I/Q modulated, so they can be expressed as complex signals:

3. $$\begin{aligned} I + jQ &= (I_{chip} \cdot I_S - Q_{chip} \cdot Q_S) \\ &\quad + j(I_{chip} \cdot Q_S + Q_{chip} \cdot I_S) \\ &= (I_{chip} + jQ_{chip}) \cdot (I_S + jQ_S) \\ &= A_{chip} \cdot A_s \cdot e^{j(\phi_{chip} + \phi_S)} \end{aligned}$$

where: A_{chip} and $e^{j\phi_{chip}}$ are the amplitude and the phase of the $I_{chip} + jQ_{chip}$ signal; A_s and $e^{j\phi_s}$ are the amplitude and the phase of the $I_S + jQ_S$ signal;

Therefore, the amplitude (A) of the resulting I + jQ signal is the product of the amplitudes of both signals. Its phase (ϕ) is the sum of their phases.

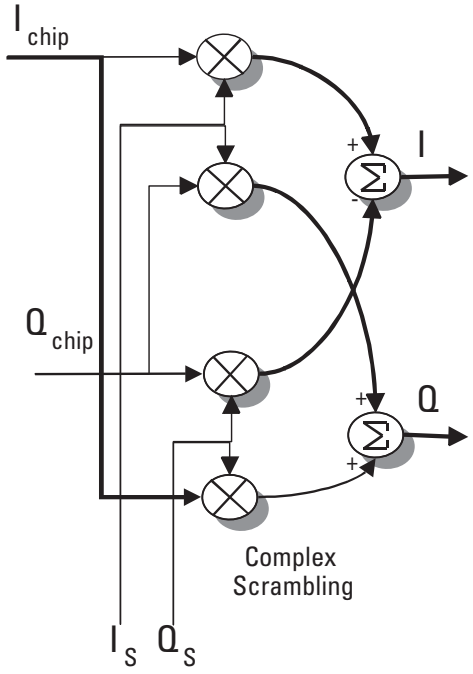


Figure 3. Complex scrambling block diagram

The rest of this application note will refer to the original complex data signal spread into chips as the *chip* signal and to its I and Q components as I_{chip} and Q_{chip}, respectively. The resulting complex signal will be referred to as the *final* signal and its I and Q components simply as I and Q, respectively.

For simplicity, a signal with only two channels (one in the I path and the other one in the Q data paths) is used to explain this concept in the I/Q plane (see Figure 4).

In the case of two channels with the same amplitude (same amplitude for I_{chip} and Q_{chip}), the chip signal maps onto a QPSK constellation. The scrambling signal also maps onto a QPSK constellation (since the scrambling I_S and Q_S signals have values of 1 or -1).

In the case of two channels with different amplitudes, the chip signal maps onto a rectangular 4-QAM constellation. The scrambling signal still corresponds to a QPSK constellation.

What is the final constellation for the two cases in Figure 4?

Figures 5a through 5d illustrate what happens for a single chip point in the original QPSK constellation (Case 1). The original chip signal is the same for all the figures (from 5a to 5d) and the scrambling signal is different. The amplitude of the final signal is the product of the amplitudes of the chip and scrambling signals. The phase of the scrambling signal is added to the phase of the original chip signal (45°). Any point from the original QPSK chip constellation is rotated by 45°, -45°, 135°, or -135°, depending on the values for I_S and Q_S at that time. For example, in Figure 5a, the phase of the scrambling signal is +45°, so 45° is added to the phase of the original chip point.

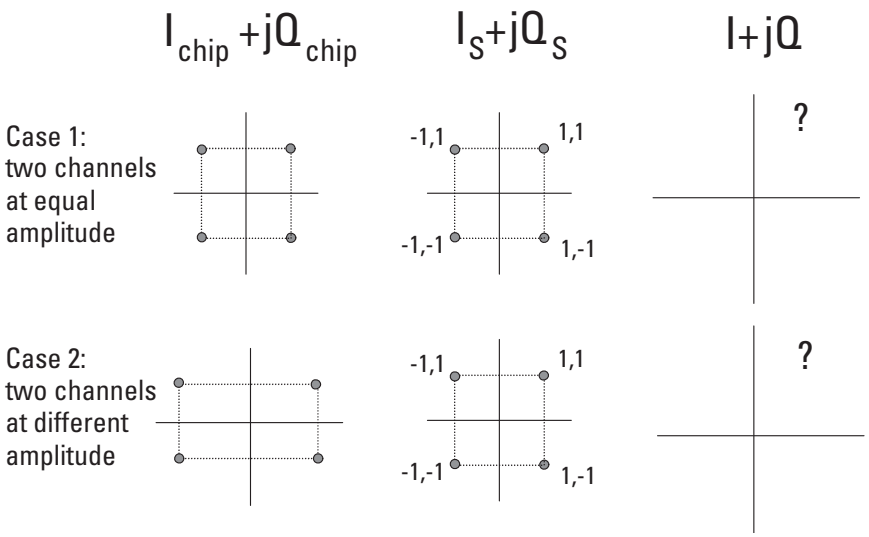


Figure 4. What is the result of complex scrambling the chip and scrambling signals for these two cases?

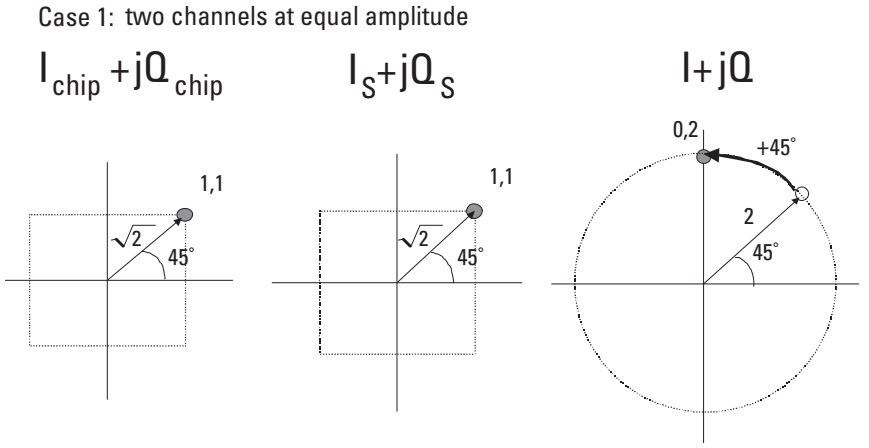


Figure 5a. Scrambling signal at +45°

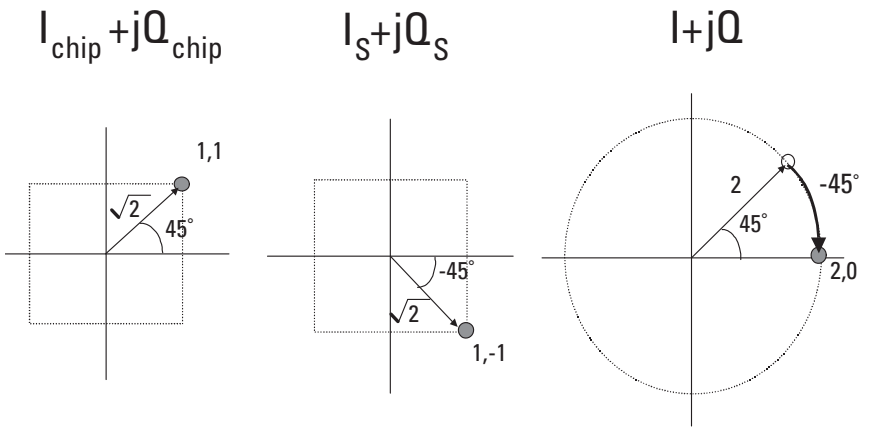


Figure 5b. Scrambling signal at -45°

Therefore, in the case of two channels with equal amplitudes (QPSK constellation) all the points of the final constellation lie on top of the I or Q axis. The result is a QPSK constellation aligned with the I/Q axes (rotated 45° from the original constellation).

In the case of two channels with unequal amplitudes, the amplitude of the resulting constellation is also constant, as shown in Figure 6. The chip points from the original 4-QAM constellation are rotated by 45°, -45°, 135°, or -135°, since the scrambling signal still corresponds to a QPSK constellation. However, the final constellation has eight points distributed around a circle, since the phases for the chip points in the original constellation are different from 45°, -45°, 135°, and -135°. The angular distribution of the points is determined by the relative amplitudes of the two channels (I_{chip} and Q_{chip}). Figure 6 shows the resulting constellations for these two cases.

Review: Why is complex scrambling required?

In W-CDMA and cdma2000, the mobile phone can transmit multiple I/Q multiplexed channels at different power levels. In addition to providing differentiation among users, complex scrambling distributes the power evenly between the I and Q axes.

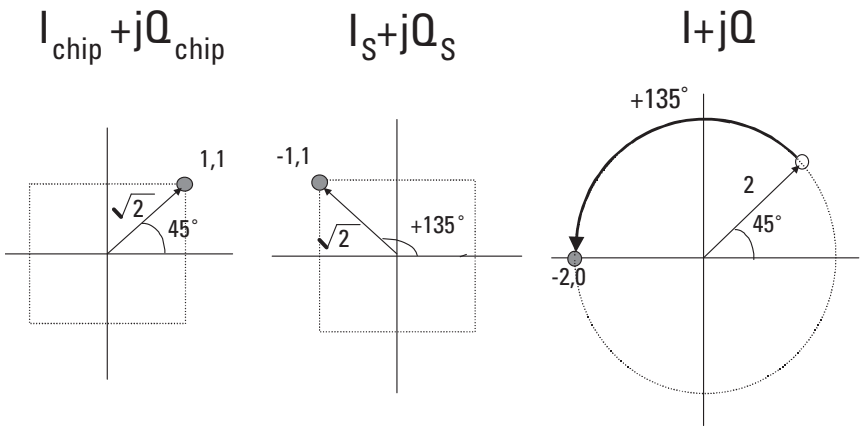


Figure 5c. Scrambling signal at +135°

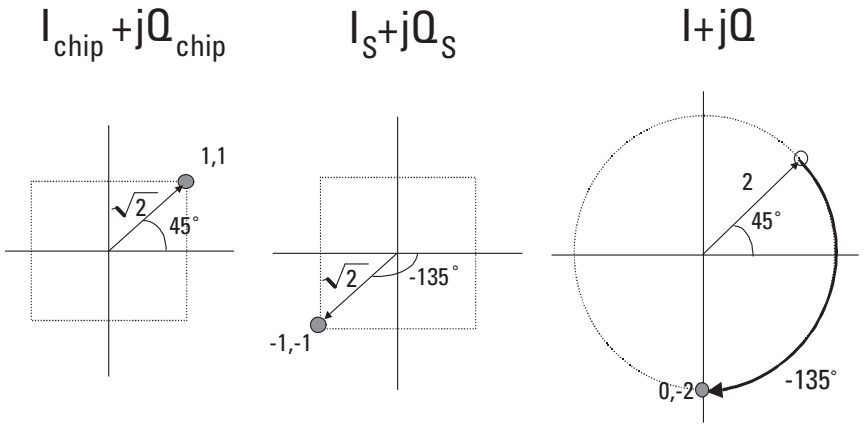


Figure 5d. Scrambling signal at -135°

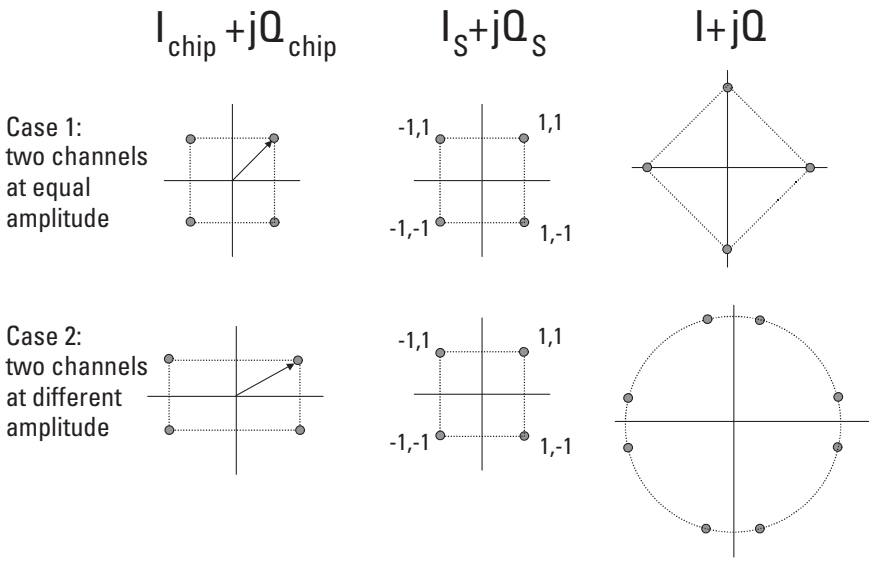


Figure 6. Complex scrambling distributes the power evenly between the I and Q axes

3. HPSK

2G systems commonly use modulation formats that limit transitions through zero in the reverse link (uplink). For example, cdmaOne uses OQPSK (Offset Quadrature Phase Shift Keying). This reduces the peak-to-average power ratio of the signal, which allows for a more efficient amplifier, maximizing battery life.

However, in complex scrambling, if random PN signals are assigned to I_S and Q_S, transitions from any point to any point in the final constellation are possible. This results in a high peak-to-average ratio when compared to existent 2G formats for the reverse link. Figure 7 shows the constellation diagrams of an OQPSK signal and a QPSK signal with basic complex scrambling. The spreading technique that uses basic complex scrambling and PN signals for I_S and Q_S is known as Pseudo-Noise Complex Quadrature Phase Shift Keying (PNCQPSK).

3G systems use Hybrid Phase Shift Keying (HPSK), also known as Orthogonal Complex Quadrature Phase Shift Keying (OCQPSK), to reduce the peak-to-average power ratio of the signal. HPSK is a variation of basic complex scrambling that eliminates zero-crossings for every second chip point. It accomplishes this by using a specific repeating sequence (or function) as the scrambling signal and by choosing specific orthogonal codes to spread the different channels.

How does HPSK work?

Basically, HPSK uses complex scrambling with a fixed repeating function as the scrambling signal. This function is known as the Walsh rotator, and it is defined as $W_0 = \{1,1\}$ for I_S, and $W_1 = \{1, -1\}$ for Q_S.

Figure 8 illustrates what happens in the I/Q plane. In this case, two consecutive chip points fall at the same place on the I/Q plane. The repeating Walsh rotator sequence ($I_S = W_0 = \{1,1\}$; $Q_S = W_1 = \{1,-1\}$) is used as the scrambling signal. For two consecutive identical chip points, the first one is rotated by +45°, and the second one by -45°, which ensures that they will be 90° apart in the final constellation and the transition between them does not go through zero.

This technique assumes pairs of consecutive identical chips. This can be achieved by using only even-numbered Walsh functions to spread the data from the different channels. Even-numbered Walsh functions consist of pairs of identical bits. For example, for a Walsh code length of 8 bits: $W_0 = \{1,1,1,1,1,1,1,1\}$, $W_2 = \{1,1,-1,-1,1,1,-1,-1\}$, and so forth. Therefore, using only even-numbered Walsh functions to spread the different channels ensures that the chip signal consists of pairs of identical consecutive chips.

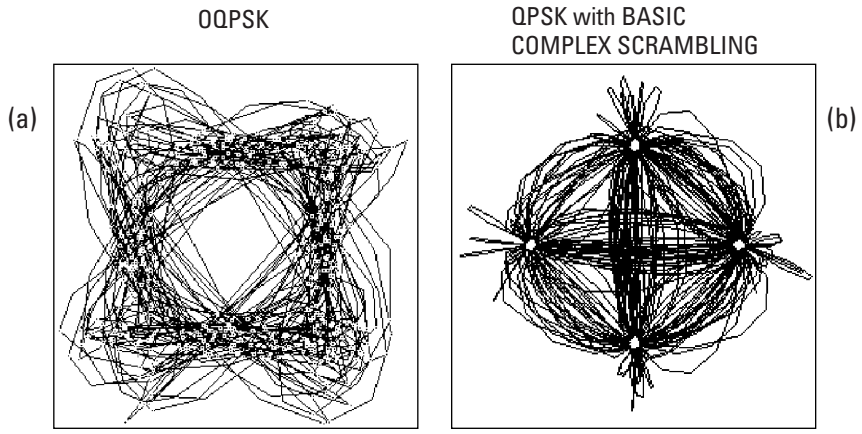


Figure 7. Constellation of (a) an OQPSK signal versus (b) a QPSK signal with basic complex scrambling (Agilent Technologies E4406A VSA series transmitter tester screen displays)

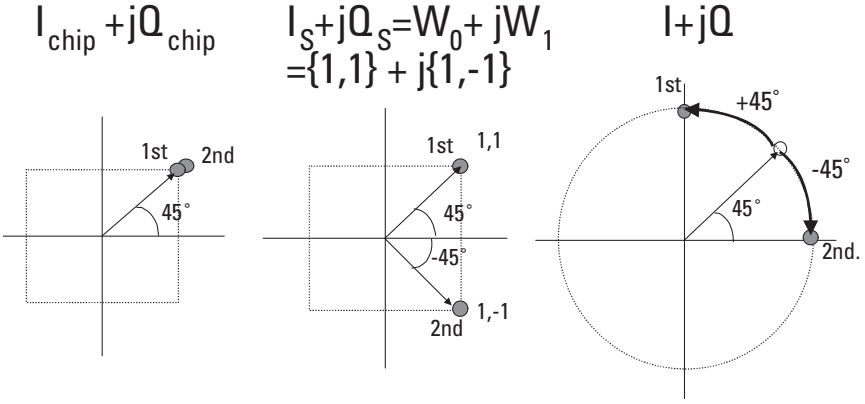


Figure 8. Complex rotator rotates first and second chip points by +45° and -45°, respectively

Figure 9 shows a generic block diagram where the Walsh rotator is used as the scrambling signal. To simplify the diagram, only two channels at the same amplitude are transmitted. The orthogonal functions chosen in this case to spread each one of the channels are 8-bit Walsh codes 0 and 2, respectively. For example, if the data signal is $I_D = 1$ and $Q_D = -1$, the chip signal is $I_{chip} = 1,1,1,1,1,1,1,1$ and $Q_{chip} = -1,-1,1,1,-1,-1,1,1$. The constellation of this signal consist of the complex points $I_{chip} + jQ_{chip} = \{1 - j1, 1 - j1, 1 + j1, 1 + j1, 1 - j1, 1 - j1, 1 + j1, 1 + j1\}$. Therefore, the chip signal consists of pairs of identical consecutive points. Each pair is multiplied with the scrambling signal formed by the Walsh rotator $I_S + jQ_S = W_0 + jW_1 = \{1 + j1, 1 - j1\}$. Therefore, the first point in the pair is phase shifted by +45°, and the second one by -45°, which ensures that they will be 90° apart in the final constellation.

In the real system, the length of the orthogonal code for each channel depends on that channel's data rate.

HPSK limits the choice of available orthogonal spreading codes. However, this limitation does not place a large constraint, because a single mobile does not need to support a large number of traffic channels. In most cases, there are sufficient orthogonal codes to handle most channel configurations for both cdma2000 and W-CDMA.

In HPSK, transitions through zero are only eliminated for pairs of consecutive points. Transitions across pairs may go through zero. For example, for four consecutive points, the transition between the first and the second points (or the third and the fourth) does not go through zero. However, the transition between the second and the third point may go through zero. The basic idea behind HPSK is to minimize zero-crossings to improve the peak-to-average power ratio of the signal. Figure 10 shows the constellations of two signals: the first one without HPSK spreading, and the second one with HPSK spreading. The constellation for HPSK shows fewer zero-crossings.

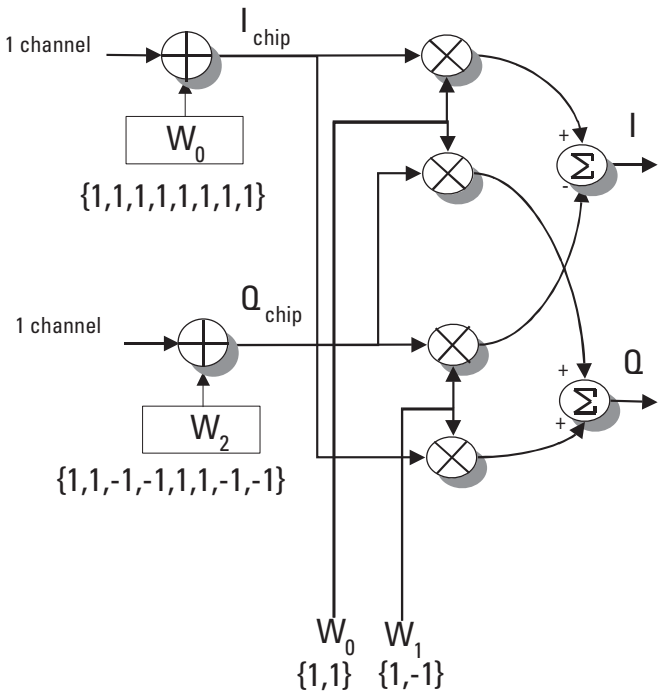


Figure 9. HPSK: Complex scrambling with Walsh rotator and even-numbered Walsh codes

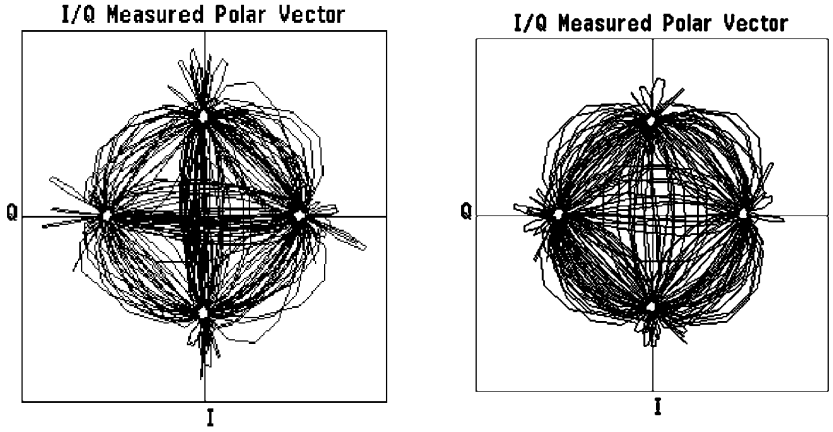


Figure 10. Constellation of signal (a) without HPSK spreading and (b) with HPSK (E4406A VSA series transmitter tester displays)

In addition to minimizing zero-crossings, HPSK eliminates 0° phase shift transitions for every second chip point. A 0° phase transition occurs when two consecutive points are at the same place on the final constellation. This causes overshooting trajectory, which increases the peak-to-average power ratio of the signal, as shown in Figure 11.

HPSK forces 90° transitions between pairs of consecutive points. This minimizes 0° phase transitions, which further reduces the peak-to-average power ratio of the signal.

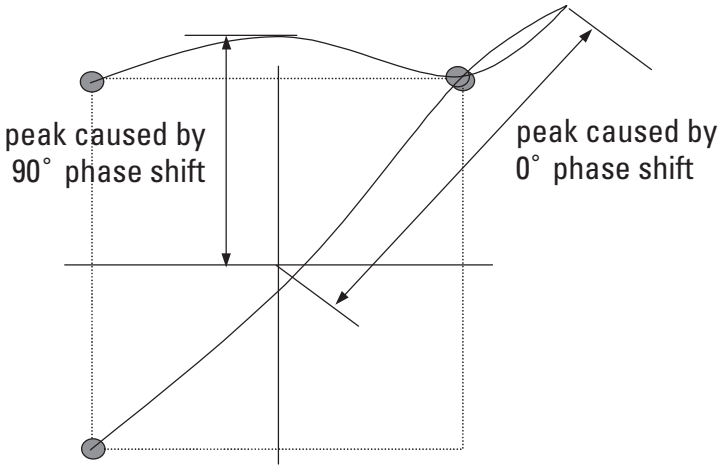


Figure 11. 0° phase shift transitions cause higher signal overshoot

Primary PN function

As shown so far, HPSK uses a Walsh rotator and the right choice of orthogonal functions for the different channels to minimize zero-crossings and 0° transitions in the final constellation. This improves the peak-to-average power ratio.

The real HPSK block diagram is more complex. After complex multiplication with the Walsh rotator, a primary PN spreading code $PN^{(1)}$ is applied to the final I and Q signals to allow for identification of the mobile and correlation at the receiver. The $PN^{(1)}$ sequence is the same for I and Q and it does not affect the number of 90° transitions. Figure 12 shows a block diagram of HPSK with the primary PN function.

The $PN^{(1)}$ spreading code does not necessarily have to be applied after the complex scrambling. It can instead be directly multiplied with the I and Q components of the scrambling signal before the complex scrambling. The final result is the same in both cases.

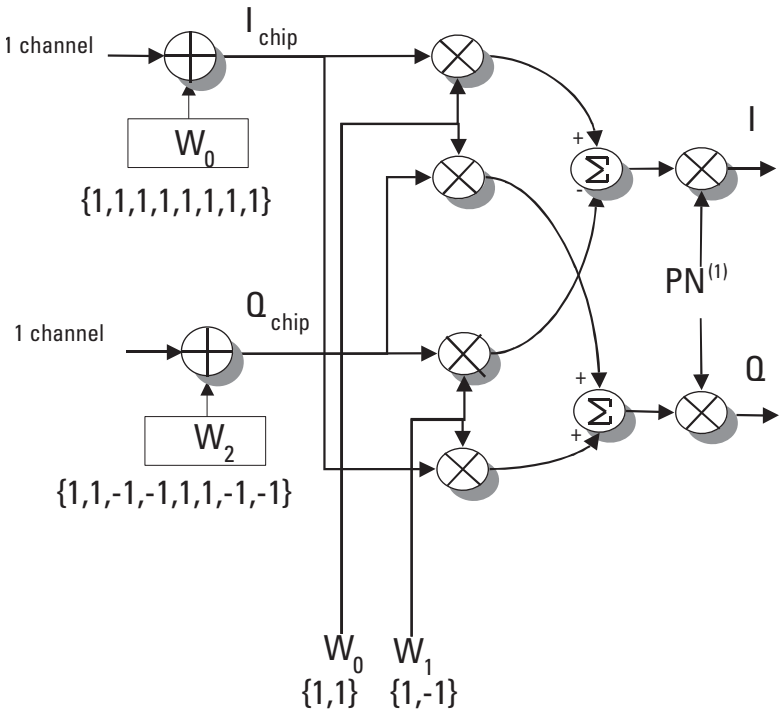


Figure 12. HPSK: Complex scrambling, Walsh rotator, even-numbered Walsh codes and primary PN sequence

Figure 13 shows why the $PN^{(1)}$ sequence does not affect the number of 90° transitions. The $PN^{(1)}$ sequence is always the same for I and Q. Therefore, a value of $PN^{(1)}$ of +1 does not change the location of the constellation point. A value of -1 inverts the location of the final constellation point. In this example, the final constellation points (after complex scrambling with the Walsh rotator and before applying the $PN^{(1)}$ sequence) correspond to (0,1) and (1,0). The figure shows the four possible cases.

In the first case, the value of $PN^{(1)}$ is +1 for both points. Therefore the constellation does not change. In the second case, the value of $PN^{(1)}$ is -1 for the first point in a pair and +1 for the second point. The location of the first constellation point changes, but the resulting constellation points are still 90° apart. In the third case, the value of $PN^{(1)}$ is +1 for the first point in a pair and -1 for the second point. Again, the resulting constellation points are 90° apart. In the fourth case, the value of $PN^{(1)}$ is -1 for both the first and second points. The location of both constellation points is inverted, but the resulting constellation points are still 90° apart.

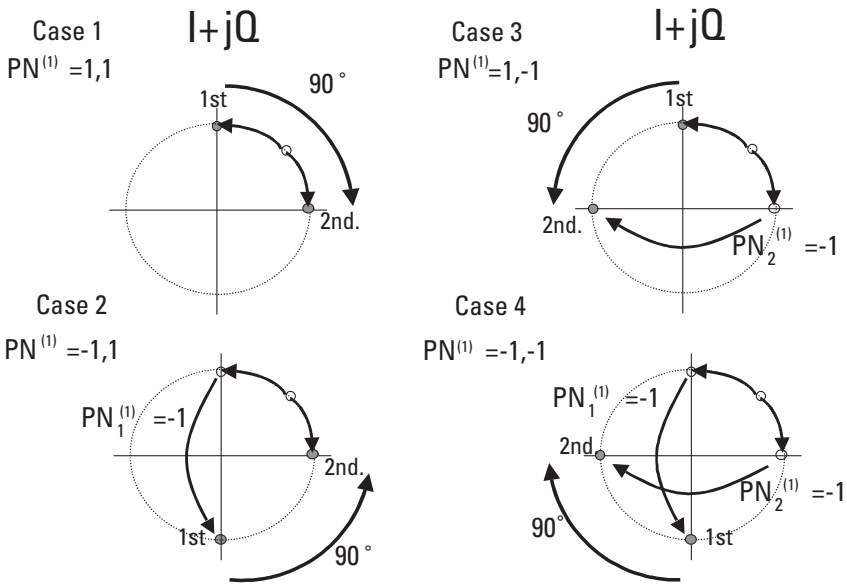


Figure 13. Effect of primary PN sequence

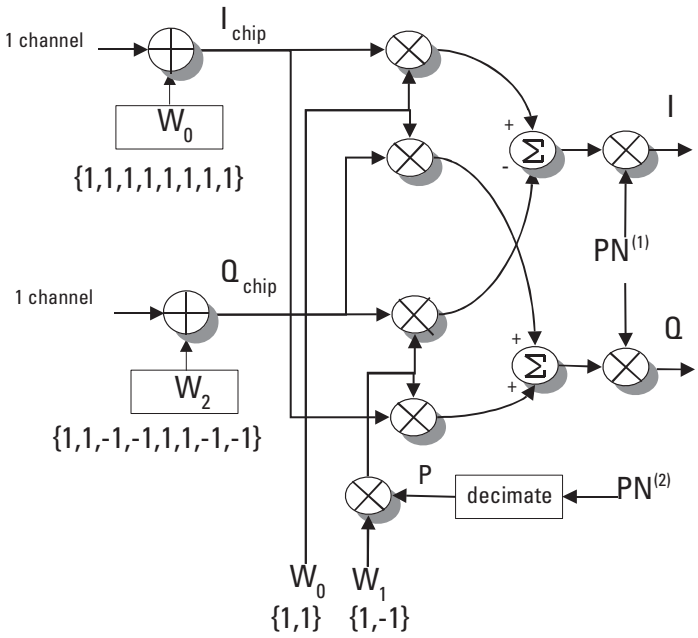


Figure 14. HPSK: Complex scrambling, Walsh rotator, even-numbered Walsh codes and primary and secondary PN sequences

Secondary PN function

A decimated secondary PN spreading code (P) is multiplied with the Q component of the Walsh rotator (W_1 = {1,-1}), as shown in Figure 14. The secondary PN spreading code minimizes Multi-Access Interference (MAI), thereby improving reception at the receiver [1].

P is a decimated version of the real chip rate sequence $PN^{(2)}$. For example, for a decimation factor of two, P holds its value for two chip time periods, which effectively makes its rate half the chip rate. P randomizes the direction of the phase rotation while keeping the phase difference of 90° between pairs of consecutive final points.

Figure 15 illustrates the effect of P in the final constellation. In the first case, P = 1. Therefore, the Q component of the scrambling signal is W_1 = {1,-1}. The first chip point is rotated by +45°, and the second by -45°. In the second case, P = -1. Therefore, the Q component of the scrambling signal is now {-1,1}. The first chip point is rotated by -45° and the second by +45°. This still avoids zero-crossings and 0° transitions between these two chip points.

Final HPSK spreading (scrambling) function

When $PN^{(1)}$ and P are included, the total spreading (or scrambling) function for HPSK is:

4. $I_S + jQ_S = PN^{(1)} \times (W_0 + jP \times W_1)$

where: W_0 = {1,1}; and W_1 = {1,-1}.

Since W_0 = {1,1}, this function can be removed from the equation. The

function can then be expressed as:

5. $I_S + jQ_S = PN^{(1)} + jPN^{(1)} \times P \times W_1$

where: W_0 = {1,1}; and W_1 = {1,-1}.

W-CDMA and cdma2000 may implement this function in different ways. Figure 16 shows the W-CDMA implementation as it is currently (9/99) being proposed.

In W-CDMA, Orthogonal Variable Spreading Functions (OVSFs) are used instead of Walsh codes. The DPCCH is always spread with a 256-bit code 0 ($C_{256,0}$), which corresponds to {1,1,1,1,1,1...}, so it does not need to be implemented in the block diagram. When a single traffic channel is transmitted, the OVSF code for that channel depends on its data rate. Because OVSF 0 = W_0 = {1,1}, this section of the Walsh (or OVSF) rotator does not need to be implemented in the block diagram.

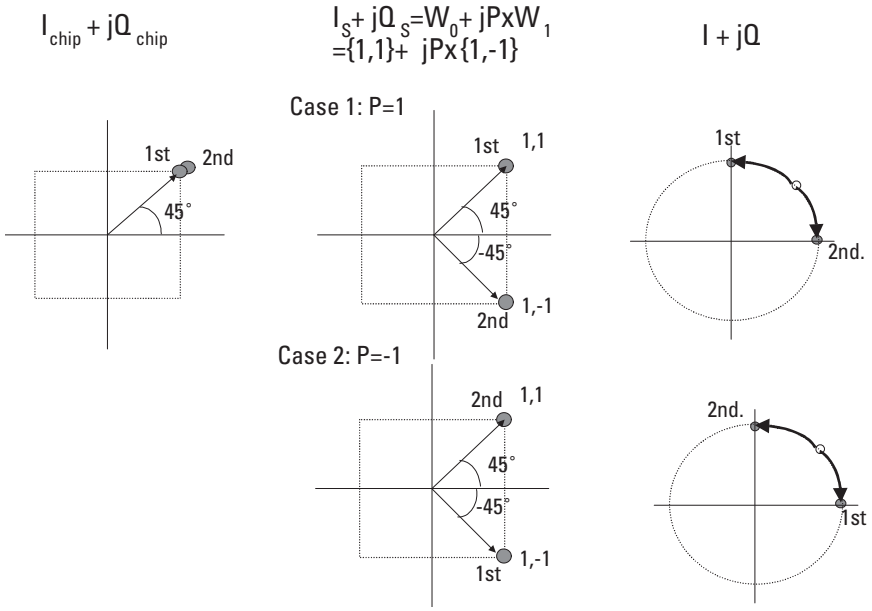


Figure 15. The decimated secondary PN sequence (P) randomizes the direction of the rotation

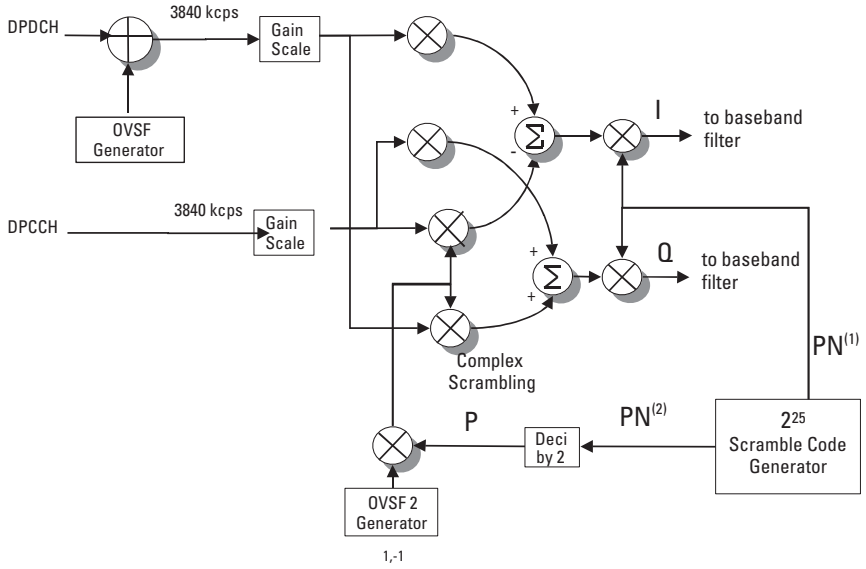


Figure 16. Proposed uplink structure for W-CDMA (3GPP)

A 2^{25} gold code generator is used to obtain the two pseudorandom sequences. The generator uses two sets of shift registers to generate the gold codes.

Figure 17 shows the block diagram for the reverse link of a cdma2000 Spread Rate 3 (SR3) system with the R-Pilot and a traffic channel.

In cdma2000, the Pilot is not spread with any Walsh code, which corresponds to Walsh code 0, {1,1,1,1,1,1...}. The fundamental traffic channel is always spread with Walsh 16 code 4, {1,1,1,1,-1,-1,-1,-1,1,1,1,1,-1,-1,-1,-1}. The $PN^{(1)}$ is formed by applying a user's 42-bit code mask to the original cdmaOne 42-bit long code, and scrambling the result against the cdmaOne I short code. P is created by delaying the long code by one chip, scrambling it with original cdmaOne Q short code, and decimating by a factor of two.

The names $PN^{(1)}$, $PN^{(2)}$, and P are not used in W-CDMA or cdma2000, but have been added to both block diagrams for clarification.

What is the benefit of HPSK?

The probability of a zero-crossing for a regular QPSK or PNCQPSK signal with two channels at the same amplitude is 1/4. For HPSK, the probability of a zero-crossing is limited to every other chip point, and is therefore reduced in half (1/8). The probability of 0° phase shift transitions is also reduced from 1/4 to 1/8. All this improves the peak-to-average power ratio of the signal by approximately 1 to 1.5 dB. HPSK spreading is still advantageous when multiple channels at different amplitudes are transmitted.

Figure 18 shows the CCDF (Complementary Cumulative Distribution Function) for two signals:

1. A signal with basic complex scrambling.
This signal has been generated from a cdma2000 SR1 forward link signal with a single traffic channel (which uses basic complex scrambling). The filtering has been modified to cdma2000 reverse link filtering (which, as opposed to the forward link, does not include an equalization function).

2. A signal with HPSK spreading.
This signal is a cdma2000 SR1 reverse link signal with two channels (R-Pilot and R-FCH) at the same power level.

The CCDF curve provides the distribution of particular peak-to-average ratios versus probability. In this case, for a probability of 0.1%, the peak-to-average ratio of the HPSK signal is about 1 dB lower than the signal with basic complex scrambling. Please note that this plot does not provide a straight comparison between basic complex scrambling and HPSK. The coding between forward and reverse link signals is different, which may impact the results. However, the plot is indicative of the performance of HPSK spreading versus basic complex scrambling.

Signals with high peak-to-average power ratio may saturate the power amplifier, causing higher interference in the adjacent channels and a reduction of system capacity. To minimize this, the amplifier must be designed with a larger back-off, which in turn reduces amplifier efficiency. Therefore, high peak-to-average power ratios reduce battery life, one of the critical characteristics of the mobile phone.

Review: What is HPSK?

HPSK is a spreading technique that uses complex scrambling with a Walsh rotator and selected orthogonal spreading codes for the different channels to minimize the peak-to-average power ratio of the signal.

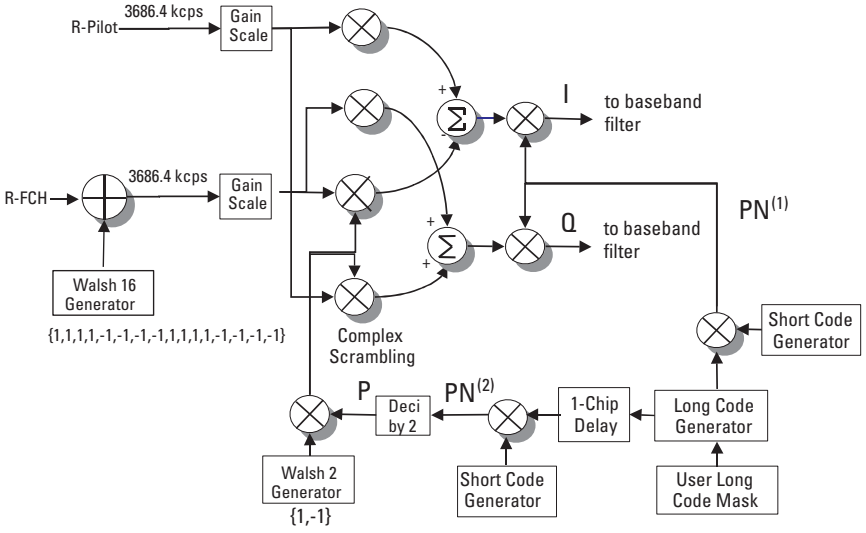


Figure 17. Proposed reverse link structure for cdma2000 SR3 systems

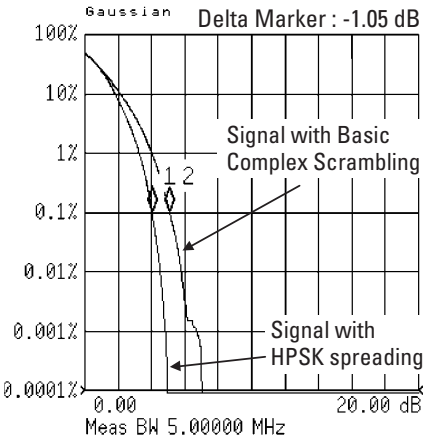


Figure 18. CCDF comparison between signals with and without HPSK (E4406A VSA series transmitter tester display)

4. Modulation quality measurements for the reverse link of W-CDMA and cdma2000 systems

As shown earlier, the reverse link (uplink) structure for W-CDMA and cdma2000 systems is very different from that of 2G systems. The main differences are:

- Each mobile can transmit several channels at different power levels.
- HPSK spreading is used to limit the peak-to-average power ratio of the reverse link signal.

These differences will probably affect the way modulation quality is defined for the reverse link. For example, some sort of code-domain power and QPSK/HPSK demodulation/de-spreading may be necessary to provide the appropriate testing.

While the measurement methodology is being defined, existing test equipment can be used to obtain an indication of the modulation quality of the signal. The easiest methodology is to configure the signal so that it maps onto a known constellation (for instance QPSK or 16QAM) and measure uncoded EVM (before HPSK de-spreading at the receiver side). Three suggested configurations are given below. The screen images were obtained using the Agilent Technologies instruments shown in Figure 19.

- **QPSK** constellation (see Figure 20): Activate DPCCH (or R-Pilot) and one traffic channel at the same power level.

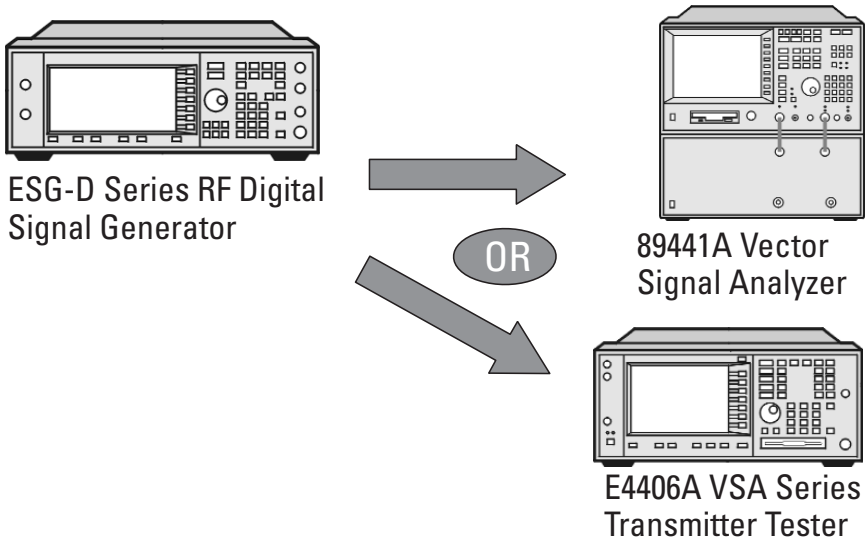


Figure 19. Instrument setup

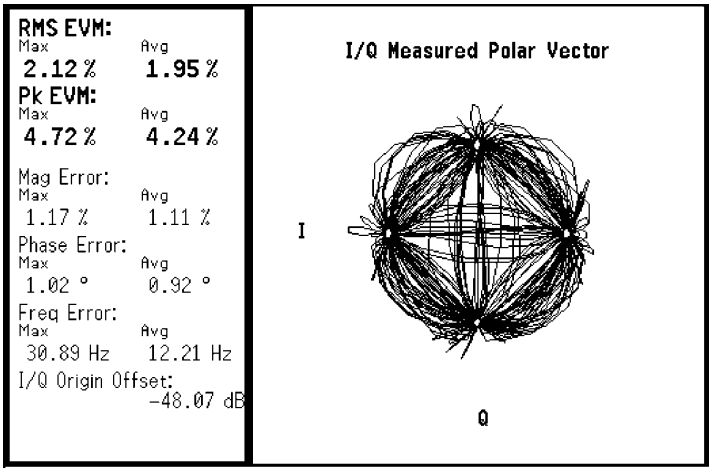


Figure 20. EVM (uncoded) and constellation for a W-CDMA signal with two channels at the same amplitude level (E4406A VSA series transmitter tester display)

- **8PSK** constellation (see Figure 21): Activate DPDCH (or R-Pilot) and one traffic channel 7.65 dB below.

- **16QAM** constellation (see Figure 22): Activate DPCCH (or R-Pilot) and two traffic channels at the same power level.

The uncoded EVM measurement does not reveal faults in the coding and spreading but provides an indication of the quality of the baseband filtering, modulation, and the IF and RF sections. For example, errors in the baseband filtering, I/Q impairments, compression at the amplifier, and LO instability increase EVM. Most of these errors can be identified by analyzing the different modulation displays (constellation, magnitude of error vector versus time, phase error versus time, magnitude error versus time, and so forth). For example, a gain imbalance between I and Q causes an asymmetric constellation, as shown in Figure 23.

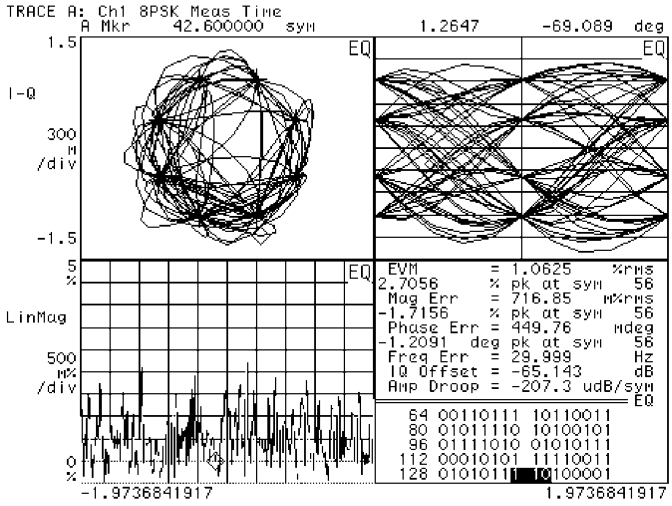


Figure 21. EVM (uncoded) and constellation for a W-CDMA signal with two channels that have an amplitude difference of 7.65 dB (89441A vector signal analyzer display)

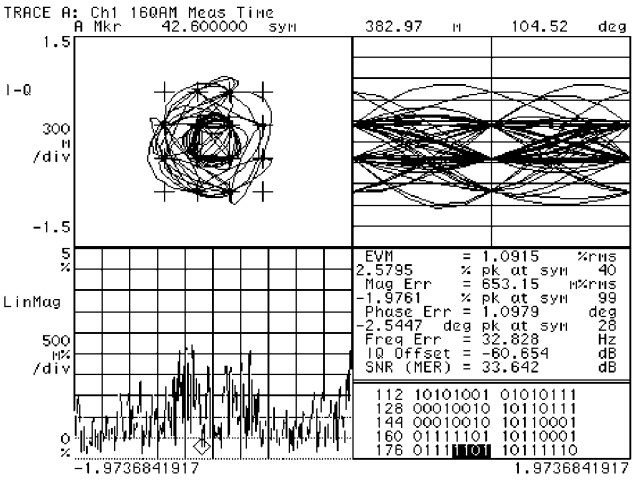


Figure 22. EVM (uncoded) and constellation for a W-CDMA signal with three channels at the same amplitude level (89441A vector signal analyzer display)

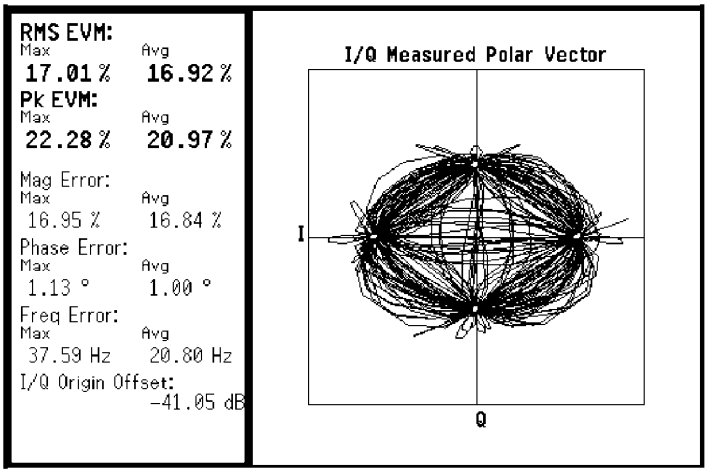


Figure 23. EVM (uncoded) and constellation for a W-CDMA signal with an I/Q gain impairment (E4406A VSA series transmitter tester display)

5. Summary

This application note has explained why HPSK has been selected as the spreading technique for the reverse link (uplink) of 3G systems such as W-CDMA and cdma2000. The main points of the application note are:

- In W-CDMA and cdma2000 systems, the mobile phone can transmit multiple I/Q multiplexed channels at different power levels.

- Complex scrambling facilitates this by distributing the power evenly between the axes.

- HPSK is a variation of complex scrambling that uses a Walsh rotator and specific orthogonal (Walsh or OVSF) spreading functions to minimize zero-crossings and 0° phase shift transitions. This improves the peak-to-average power ratio of the signal.

- The application note shows how to start making modulation quality measurements on the reverse link of W-CDMA and cdma2000 signals using existing instrumentation.

6. Glossary

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
CCDF	Complementary Cumulative Distribution Function
CDMA	Code Domain Multiple Access
cdmaOne	IS-95 standard-based CDMA system
cdma2000	cdmaOne derivative, 3G proposal
DPCCH	Dedicated Physical Control CHannel
DPDCH	Dedicated Physical Data CHannel
EVM	Error Vector Magnitude
GMSK	Gaussian Minimum Shift Keying
HPSK	Hybrid Phase Shift Keying
I/Q	In-Phase/Quadrature
IF	Intermediate Frequency
LO	Local Oscillator
MAI	Multi Access Interference
OCQPSK	Orthogonal Complex Quadrature Phase Shift Keying
OQPSK	Offset Quadrature Phase Shift Keying
OVSF	Orthogonal Variable Spreading Function
PN	Pseudo-Noise
PNCQPSK	Pseudo-Noise Complex Quadrature Phase Shift Keying
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
R-FCH	Reverse Fundamental CHannel
R-Pilot	Reverse Pilot
R-SCH	Reverse Supplemental Channel
SR	Spreading Rate
W-CDMA	Wideband CDMA, 3G proposal

7. References

[1] *Proposal for Orthogonal Complex QPSK,* Tdoc SMG2 UMTS 85/98.

[2] JaeRyong Shim and SeungChan Bang, *Spectrally Efficient Modulation and Spreading Scheme for CDMA Systems,* IEE, August 19, 1998.

[3] *Comments on ACP Simulation of Nokia and BER Simulation Results on OCQPSK,* Tdoc SMG2 UMTS-L1 211/98.

[4] *BER Simulation Results for HPSK (OCQPSK),* Tdoc SMG2 UMTS-L1 225/98.

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