TSG-RAN Working Group 1 meeting #8 ***TSGR1#8(99)h64***
New York, USA
12 Oct – 16 Oct 1999

Agenda Item:

Source: Sony, Panasonic, Ericsson

Title: Common pilot pattern

Document for: Discussion

---

1. Introduction

In the last meeting, two different patterns for the common pilot for Tx diversity were discussed.

pattern 2
Primary CPICH Ant 1 A, A, A, A, A, A, A, A , A, A,
Ant 2 A,-A,-A, A, A, -A, -A, A, A,-A,

pattern 3
Primary CPICH Ant 1 A, A, A, A, A, A, A, A , A, A,
Ant 2 A,-A, A,-A, A, -A, A,-A, A,-A,

The pilot pattern 2 has been approved in the last meeting at Hanover.

In TdocR1-99g62, Samsung and Nokia proposed to use pattern3, claiming that it has a capability to acquire the frequency offset up to +/-7.5kHz. In that document, we have a concern on the analysis given on equation (1). Our analysis shows that the frequency acquisition range using the pilot pattern of #3 is limited to +/-3.75kHz. In addition, we show that the differential detection can be applied to acquire frequency offset up to +/-7.5kHz using current pilot pattern of #2.

2. The analysis of acquisition rage using proposal#3

The following analysis is given based on assumption and notation shown below:

Channel Characteristics from Ant#1: a_1 (Complex constant)

Channel Characteristics from Ant#2: a_2 (Complex constant)

$\Delta w = 2pf$ frequency offset within 256 chip

q : absolute phase offset between Tx and Rx

Define the transmitted signal from each antenna of basestation as follows.

$$S_1(t) = x_1(t)\cos w_c t - y_1(t)\sin w_c t$$
$$S_2(t) = x_2(t)\cos w_c t - y_2(t)\sin w_c t$$

$$I(t) = \tilde{x}(t)\cos(\Delta wt + q) + \tilde{y}(t)\sin(\Delta wt + q)$$

$$Q(t) = \tilde{y}(t)\cos(\Delta wt + q) - \tilde{x}(t)\sin(\Delta wt + q)$$

With presence of frequency offset , the observed signal seen by a receiver can be expressed as follows,

where

$$\tilde{x}_1 + j\,\tilde{y}_1 = a_1(x_1 + jy_1) \qquad \ldots\ldots\ldots\ldots(A)$$

$$\tilde{x}_2 + j\,\tilde{y}_2 = a_2(x_2 + jy_2)$$

And the complex envelope of the received signal can be expressed as,

$$U(t) = I(t) + jQ(t)$$
$$= (\tilde{x}(t) + j\tilde{y}(t))e^{-j(\Delta wt+q)}$$
$$= [(\tilde{x}_1(t) + j\tilde{y}_1(t)) + (\tilde{x}_2(t) + j\tilde{y}_2(t))]e^{-j(\Delta wt+q)}$$

After the despreading operation, signal seen by a receiver is,

$$Z(kT) = \int_{(k-1)T}^{kT} U(t)C^*(t)dt = Zi(kT) + jZq(kT)$$
$$= \int_{(k-1)T}^{kT} [a_1 D_1(t) + a_2 D_2(t)]C(t)e^{-j(\Delta wt+q)}C^*(t)dt$$

where T is in 256 PN chip unit.

With the substitution of equation (A),

$$= [a_1((x_1(t) + jy_1(t)) + a_2(x_2(t) + jy_2(t))]e^{-j(\Delta wt+q)}$$
$$= [a_1 Tx_1(t) + a_2 Tx_2(t)]e^{-j(\Delta wt+q)}$$
$$= [a_1 D_1(t)C(t)) + a_2 D_2(t)C(t)]e^{-j(\Delta wt+q)}$$

With assumptions $C(t)C^*(t) = |C(t)|^2 = 1$, a_1, a_2 constant over despreading period, and since the pilot pattern $D_1(t) = D_2(t) = A$ for $(k-1)T \le t \le kT$, the above equation can be transformed as

$$Z(kT) = a_1\int_{(k-1)T}^{kT} Ae^{-j(\Delta wt+q)}dt + a_2\int_{(k-1)T}^{kT} Ae^{-j(\Delta wt+q)}dt$$
$$Z((k+1)T) = a_1\int_{kT}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt + a_2\int_{kT}^{(k+1)T} -Ae^{-j(\Delta wt+q)}dt$$
$$= (a_1 + a_2)T\frac{\sin(\Delta wT/2)}{(\Delta wT/2)}e^{-j(\Delta w(K-\frac{1}{2})T+q)}\cdot A$$
$$= (a_1 - a_2)T\frac{\sin(\Delta wT/2)}{(\Delta wT/2)}e^{-j(\Delta w(K+\frac{1}{2})T+q)}\cdot A$$
$$= \int_{(k-1)T}^{kT} [a_1 D_1(t) + a_2 D_2(t)]e^{-j(\Delta wt+q)}dt$$
$$= a_1\int_{(k-1)T}^{kT} D_1(t)e^{-j(\Delta wt+q)}dt + a_2\int_{(k-1)T}^{kT} D_2(t)e^{-j(\Delta wt+q)}dt$$

On the other hand, for $kT \le t \le (k+1)T, D_1(t) = A, D_2(t) = -A$

And again, for $(k+1)T \le t \le (k+2)T, D_1(t) = D_2(t) = A$

$$Z((k+2)T) = a_1\int_{(k+1)T}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt + a_2\int_{(k+1)T}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt$$
$$= (a_1 + a_2)T\frac{\sin(\Delta wT/2)}{(\Delta wT/2)}e^{-j(\Delta w(K+\frac{3}{2})T+q)}\cdot A$$

Now, if the despreading operation is performed over 512 chip, we obtain,

$$Z_1 = a_1 \int_{(k-1)T}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{(k-1)T}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt$$
$$= a_1 \int_{(k-1)T}^{kT} Ae^{-j(\Delta wt+q)}dt + a_1 \int_{kT}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{(k-1)T}^{kT} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{kT}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt$$
$$= Z(kT) + Z((k+1)T)$$

$$Z_2 = a_1 \int_{kT}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{kT}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt$$
$$= a_1 \int_{kT}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt + a_1 \int_{(k+1)T}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{kT}^{(k+1)T} Ae^{-j(\Delta wt+q)}dt + a_2 \int_{(k+1)T}^{(k+2)T} Ae^{-j(\Delta wt+q)}dt$$
$$= Z((k+1)T) + Z((k+2)T)$$

The differential detection for phase offset now can be applied,

$$Z_1^* \cdot Z_2 = T\frac{\sin(\Delta wT/2)}{\Delta wT/2} e^{j(\Delta w(k-\frac{1}{2})T+q)} A^*[(a_1 + a_1)^* + (a_1 - a_1)^* e^{j\Delta wT}]$$
$$\times T\frac{\sin(\Delta wT/2)}{\Delta wT/2} e^{-j(\Delta w(k+\frac{1}{2})T+q)} A[(a_1 - a_1) + (a_1 + a_1)e^{-j\Delta wT}]$$
$$= T^2\left(\frac{\sin(\Delta wT/2)}{\Delta wT/2}\right)^2 e^{-j\Delta wT}|A|^2[|a_1 + a_2|^2 e^{-j\Delta wT} + |a_1 - a_2|^2 e^{j\Delta wT} + 2(|a_1|^2 - |a_2|^2)]$$

For explanatory purpose, if we let $a = a_2 = 1$,

$$Z_1^* \cdot Z_2 = 4T^2\left(\frac{\sin(\Delta wT/2)}{\Delta wT/2}\right)^2 e^{-j\Delta w 2T}|A|^2$$

The exponential term {-j $\Delta 2w$T} suggest that

$$|2\Delta w\mathrm{T}| < p \ , \ \Delta w = 2p\Delta f$$
$$|\Delta f| < 1/4T = 15kHz$$
$$|\Delta f| < 3.75kHz$$

Therefore, the conclusion that with the use of pilot pattern 3, the upper limit for frequency acquisition range is 3.75kHz.

3. Differential Detection Using the Current Pilot Pattern

Symbol No.	1	2	3	4	5	6	7	8
ANT1	A	A	A	A	A	A	A	A
ANT2	A	-A	-A	A	A	-A	-A	A

Differential Detection	Differential detection	Differential detection
Frequency offset estimation	Frequency offset estimation	Frequency offset estimation
$|\Delta f| < 7.5kHz$	$|\Delta f| < 7.5kHz$	$|\Delta f| < 7.5kHz$

4. Conclusion:

With the analysis given above, we recommend WG1 to keep current pilot pattern for diversity antenna .