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| **Agenda item:** | **AdHoc #24 HSDPA** |
| **Source:** | **Motorola** |
| **Title:** | **HSDPA system performance based on simulation** (II update ✍ III) |
| **Document for:** | **Discussion/Information** |

## Summary:

This contribution updates [1] by correcting an error in simulating the Hybrid ARQ function which caused higher than normal residual FER. The results in **Table 1, 2** and the associated text has been modified to account for the updated simulation results.

Similar to [4] the data throughput for best effort service is summarized in this contribution for the proposed HSDPA feature set. The main differences between this study and [4] are that 30% of the power is allocated for overhead (CPICH, PICH, SCH, BCCH, etc.) and dedicated channels and that no implementation loss (1.5dB was used in [4]) is used. Throughput and other packet statistics are also shown for the single MCS level case of QPSK with a peak data rate of up to 2Mbit/s. The latter case is the first step in trying to establish release 99 throughput for best effort service. However, for this first step, the frame size is still 3.33ms and fast scheduling and acknowledgment is performed along with fast cell selection (FCS).

Results were obtained using a dynamic system simulation tool. The system simulator tool models Rayleigh and Rician fading, time evolution with discrete steps (0.667ms e.g.), adaptive modulation and coding (AMC), fast Hybrid ARQ, fast cell selection FCS, and open loop transmit diversity (STTD). The simulator also models Lognormal shadowing, delay spread, and fractional recovered power (per ray). Most of the system simulation assumptions used are described in the "Common HSDPA system simulation assumptions" contribution (TSG-R1 1094) presented in TSG-R1 meeting #15 [2]. Many assumptions are given again in **Annex B** for the reader's convenience.

## Simulation Results:

The packet data throughput for best effort service for is summarized in the following section. **Tables 1** and **2** summarize baseline performance for a data only HSDPA system with a Maximum C/I scheduler and a modified ETSI source model [2]. The different throughput metrics presented are defined in **Annex A** (note the definition of OTA throughput has been modified from [4] ). The MCS used were QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, and 64QAM R=3/4.

**Table 1. Baseline HSDPA Throughput Performance vs Load (entire system) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead**

**Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, FCS**

| #Users per sector, Max ovsf codes | Average Throughput Statistics Entire System OTA (bps) | Service (bps) | Packet call (bps) | Percent Utilization (%) | Offered Load (bps) | User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%) | %UEs with Residual FER >10-2 / >10-4 (%) |
|---|---|---|---|---|---|---|---|
| 012ue/sect, 20size32 | 2,420,614 | 393,447 | 1,588,520 | 16.2 | 405,329 | 00 / 00 / 00 / 00 / 21 | 0.0 / 0.0 |
| 037ue/sect, 20size32 | 1,997,291 | 1,148,252 | 1,274,242 | 56.4 | 1,181,163 | 00 / 00 / 00 / 08 / 43 | 0.0 / 0.0 |
| 056ue/sect, 20size32 | 2,048,895 | 1,701,205 | 1,108,079 | 80.8 | 1,744,429 | 00 / 01 / 04 / 22 / 53 | 0.0 / 0.1 |
| 075ue/sect, 20size32 | 2,341,232 | 2,167,045 | 1,041,787 | 89.5 | 2,178,208 | 02 / 05 / 12 / 32 / 58 | 0.0 / 0.0 |
| 100ue/sect, 20size32 | 2,795,915 | 2,677,923 | 1,009,988 | 92.2 | 2,704,459 | 07 / 13 / 22 / 40 / 62 | 0.0 / 0.4 |

**Table 2. Baseline HSDPA Throughput Performance vs Load (center cell) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead**

**Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, FCS**

| #Users per sector, Max ovsf codes | Average Throughput Statistics Center Cell OTA (bps) | Service (bps) | Packet call (bps) | Percent Utilization (%) | Offered Load (bps) | User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%) | %UEs with Residual FER >10-2 / >10-4 (%) |
|---|---|---|---|---|---|---|---|
| 012ue/sect, 20size32 | 2,118,458 | 427,956 | 1,466,449 | 20.1 | 454,575 | 00 / 00 / 00 / 00 / 29 | 0.0 / 0.0 |
| 037ue/sect, 20size32 | 1,836,760 | 1,313,060 | 1,159,096 | 70.9 | 1,336,101 | 00 / 00 / 00 / 10 / 51 | 0.0 / 0.0 |
| 056ue/sect, 20size32 | 1,877,997 | 1,867,354 | 984,997 | 95.8 | 1,924,122 | 00 / 02 / 07 / 30 / 62 | 0.0 / 0.1 |
| 075ue/sect, 20size32 | 2,205,427 | 2,277,296 | 926,064 | 99.8 | 2,289,468 | 03 / 09 / 17 / 41 / 65 | 0.0 / 0.0 |
| 100ue/sect, 20size32 | 2,708,189 | 2,812,661 | 922,184 | 100.0 | 2,836,978 | 12 / 19 / 29 / 48 / 69 | 0.1 / 0.3 |

From **Table 1** above, the Service throughput averaged over all sectors for the Max C/I scheduler is about 2.5Mbit/s at 89% utilization while the OTA throughput is about 2.7Mbit/s. The overall average Packet Call throughput drops from about 1.6Mbit/s to 1.0Mbit/s as the load increases. Fairness is shown in terms of the per user average packet call throughput outage cdf values given in both tables. For example, for the 12 users per sector load 21% of the users achieve an average packet call throughput of between 384kbit/s and 1Mbit/s and 79% of the users in the system achieve better than 1Mbit/s. Residual FER after Hybrid ARQ is given in terms of the percentage of users with a frame erasure rate greater than $10^{-2}$ and $10^{-4}$. For the 100 users per sector load from **Table 1**, about 99.6% of the user's FER after ARQ (residual FER) is less than $10^{-4}$ and greater than 99.9% of the users have residual FER less than $10^{-2}$. Small residual FER is important to TCP/IP performance.

**Table 2** gives center cell only statistics, and shows that the average Service throughput reaches about 2.8Mbit/s at 100% channel utilization. Average Packet Call throughput drops to about 0.9Mbit/s at 100% channel utilization. Note that the service throughput statistic can still improve once 100% channel utilization is reached for a given sector if there are fewer retransmissions due to a lower FER. As surrounding sectors reach 100% utilization the uncertainty of other cell interference level is reduced thus reducing AMC errors and resulting in fewer retransmissions.

WCDMA Release 99 throughput performance is bounded by the results given in **Table 3** and **4** below. QPSK modulation with a maximum peak rate of 2Mbit/s was modeled. Fast scheduling, a 3.33ms frame size, and conventional ARQ (no soft combining) were used. A tighter throughput bound is possible by increasing the frame size (TTI=10ms or 20ms) and increasing the scheduling and acknowledgement latency (this was not done for this study). HSDPA Packet Call throughput performance from **Tables 1** and **2** is about twice that of Release 99 throughput bound results in **Tables 3** and **4** (see **Figure 1**). For the 56 user/sector load, 47% of the data users have packet call throughput better than 1Mbit/s (see **Table 1**) while the Release 99 bound case only has 5% of its users better than 1Mbit/s (see **Table 3**).

**Table 3. QPSK with 2Mbit/s Pk Rate Throughput Performance vs Load (entire system) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead**

| #Users per sector, Max ovsf codes | Average Throughput - Entire System OTA (bps) | Service (bps) | Packet call (bps) | Percent Utilization (%) | Offered Load (bps) | User PktCall thruput cdf <32k/64k/128k/384k/1M (%) | %users with Res. FER >10-2 / 10-4 (%) |
|---|---|---|---|---|---|---|---|
| 012ue/sect, 17size32 | 1,404,140 | 385,060 | 837,077 | 34.8 | 388,711 | 0/0/1/8/69 | 0.0/19.9 |
| 037ue/sect, 17size32 | 1,453,553 | 1,026,188 | 611,505 | 79.0 | 1,044,331 | 1/3/9/34/92 | 1.1/19.9 |
| 056ue/sect, 17size32 | 1,535,192 | 1,291,871 | 501,094 | 86.3 | 1,353,155 | 7/13/25/55/95 | 0.9/10.4 |
| 075ue/sect, 17size32 | 1,562,766 | 1,386,232 | 453,189 | 89.3 | 1,406,764 | 17/25/36/59/96 | 2.3/4.7 |
| 100ue/sect, 17size32 | na | na | na | na | na | na | na |

**Table 4. QPSK with 2Mbit/s Pk Rate Throughput Performance vs Load (center cell) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead**

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes Max C/I, Mod. ETSI 30% Overhead QPSK, 2Mbit/s peak rate, noHARQ

| #Users per sector, Max ovsf codes | Average Throughput - Center Cell OTA (bps) | Service (bps) | Packet call (bps) | Percent Utilization (%) | Offered Load (bps) | User PktCall thruput cdf <32k/64k/128k/384k/1M (%) | %users with Res. FER >10-2 / 10-4 (%) |
|---|---|---|---|---|---|---|---|
| 012ue/sect, 17size32 | 1,423,765 | 547,474 | 830,334 | 43.5 | 548,755 | 0/0/0/4/69 | 0.0/20.4 |
| 037ue/sect, 17size32 | 1,450,735 | 1,266,567 | 604,962 | 96.2 | 1,296,810 | 0/3/10/37/90 | 0.0/15.7 |
| 056ue/sect, 17size32 | 1,556,237 | 1,560,540 | 464,713 | 99.9 | 1,583,330 | 8/12/31/64/96 | 2.4/9.1 |
| 075ue/sect, 17size32 | 1,584,900 | 1,599,731 | 440,446 | 100.0 | 1,657,337 | 23/32/48/70/96 | 8.0/8.4 |
| 100ue/sect, 17size32 | na | na | na | na | na | na | na |

## Conclusion:

Best effort packet data average sector service throughput for a HSDPA system with 30% overhead using a maximum C/I scheduler was shown to about 2.7Mbit/s based on quasi-static system simulations. A single ray 3kph Rayleigh faded channel was modeled for each user. At this load level up to 38% of the users in the system still achieved a packet call throughput exceeding 1Mbit/s and less than 10% achieved throughput below 32kbit/s (from **Table 1**). HSDPA has twice the throughput of the Release 99 WCDMA throughput bound (see **Table 3**).

## References:

[1] Motorola. HSDPA system performance based on simulation II. TSG-R1 document, TSGR#17(00)1397, 20-24th November 2000, Stockholm Sweden, 8pp.

[2] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)1094, 22-25th, August, 2000, Berlin, Germany, 12 pp.

[3] Motorola. Evaluation Methods for High Speed Downlink Packet Access (HSDPA). TSG-R1 document, TSGR#14(00)0909, 4-7th, July, 2000, Oulu, Finland, 15 pp.

[4] Motorola. HSDPA system performance based on simulation. TSG-R1 document, TSGR#16(00)1240, 10-13th October 2000, Pusan Korea, 12pp.

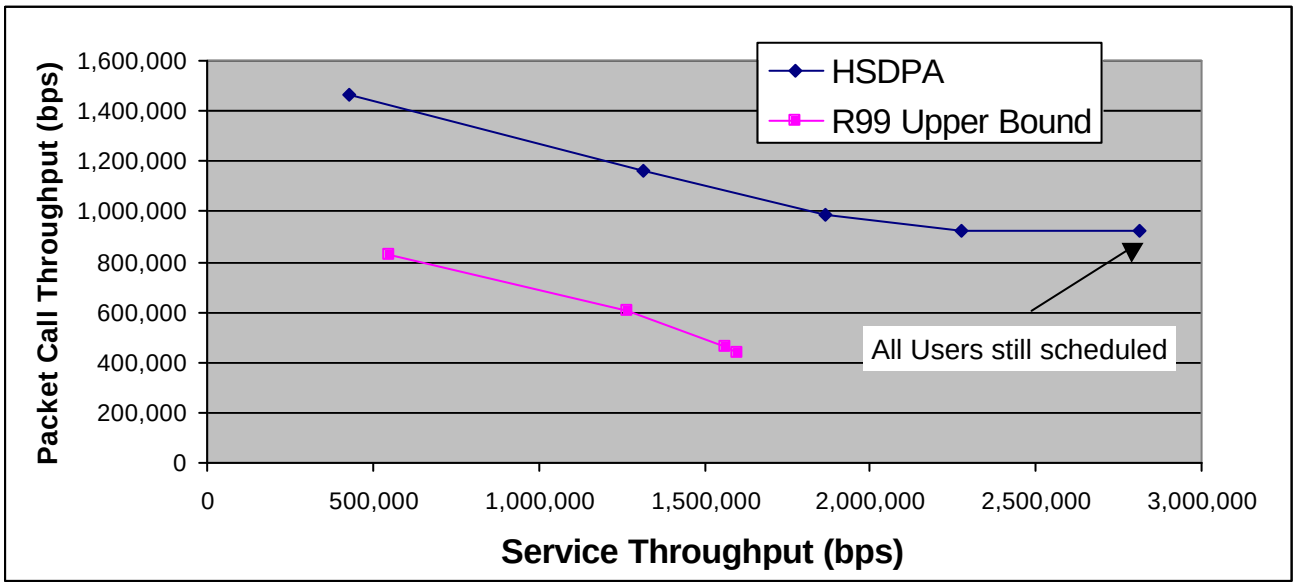


**Figure 1. Packet Call throughput vs Service Throughput for different loading.**

# Annex A

## Throughput Statistic Descriptions

**OTA** – over the air per frame throughput, Frame Rate/#transmissions. (Unaffected by time between retries.)
**Service** – total good (successful) frame bits transmitted per second for a given sector. As observed from BTS including all users and idle time. (Affected by time between retries).
**Packet Call** - total bits per packet call divided by total time to transmit packet call.
**Utilization** – percentage of time that frame intervals are active for a given sector.
(active = transmission occurs on downlink shared channel).

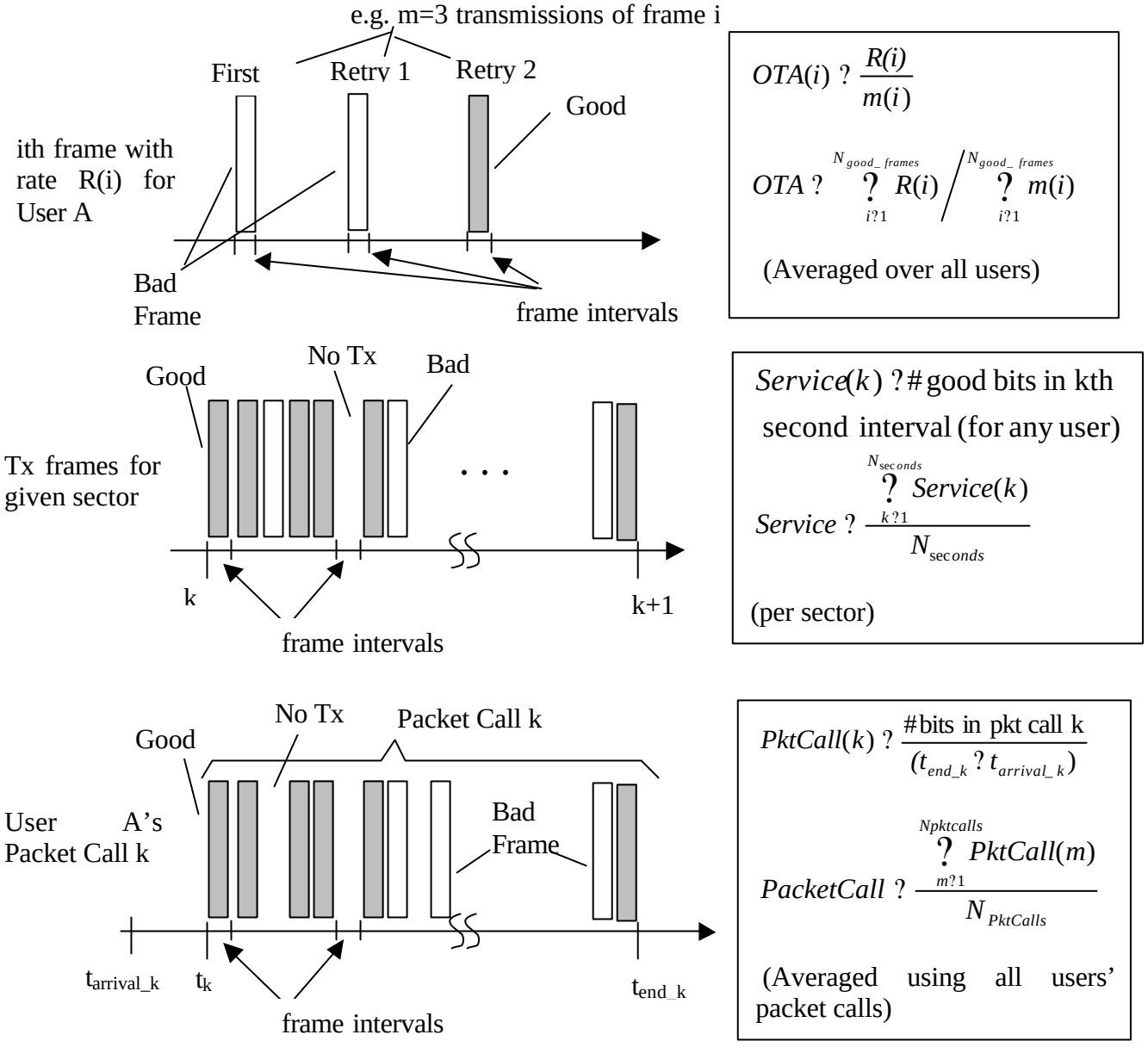


**Figure A1. Throughput Statistic Description for System Simulations.**

The service throughput for a given sector j is

$$ServiceSector(j) = \frac{1}{N_{seconds}} \sum_{k=1}^{N_{seconds}} \#\text{good bits for kth second inverval for sector j} \quad (1)$$

The service throughput averaged over all sectors in the system is

$$ServiceSystem = \frac{1}{N_{sectors}} \sum_{j=1}^{N_{sectors}} ServiceSector(j) \quad (2)$$

Also

$$ServiceSystem = \frac{\text{total good bits all sectors}}{N_{seconds} N_{sectors}} \quad (3)$$

or

$$ServiceSystem = \frac{\text{total good bits all sectors}}{(N_{good\_frames} + N_{retries} + N_{empty}) T_{frame}} \quad (4)$$

where

$N_{good\_frames}$ – total good frames over all sectors sent during simulation
$N_{retries}$ – total unsuccessful (“bad”) frames over all sectors transmitted during simulation
$N_{empty}$ – total frame intervals over all sectors where there was no transmission during sim.
$N_{lost}$ – total frame intervals over all sectors where the corresponding frame was aborted during sim.
$T_{frame}$ – frame time interval

$$OTASystem = \frac{\text{total good bits all users}}{(N_{good\_frames} + N_{retries}) T_{frame}} \quad (5)$$

$$Utilization = \frac{N_{good\_frames} + N_{retries} + N_{lost}}{N_{good\_frames} + N_{retries} + N_{empty} + N_{lost}} \quad (6)$$

$$\frac{ServiceSystem}{OTASystem} = \frac{N_{good\_frames} + N_{retries}}{N_{good\_frames} + N_{retries} + N_{empty}} \quad (7)$$

Therefore

$$\boxed{Utilization = \frac{ServiceSystem}{OTASystem}} \quad (8)$$

The packet call throughput is given by

$$PktCall(k,i,j) ? \frac{\#\text{bits in pkt call k}}{(t_{end\_k} ? t_{arrival\_k})} \quad (9)$$

where

$k$ = denotes the $k^{th}$ packet call from a group of $K$ packet calls

$i$ = denotes the $i^{th}$ user from a group of $N$ users

$j$ = denotes the $j^{th}$ drop from a group of $J$ drops

the time parameters in Equation 10 are described in Figure A1.

The user packet call throughput becomes

$$UserPktCall(i,j) ? \frac{1}{K} \sum_{k?1}^{K} PktCall(k,i,j) \quad (10)$$

# ANNEX B

## System Simulation Assumptions

The following parameters related to HSDPA features were used:

- ?? MCS selection based on CPICH measurement (RSCP/ISCP)
- ?? MCS update rate: once per 3.33 ms (5 slots)
- ?? CPICH measurement transmission delay: 1 frame
- ?? Selected MCS can be applied after 1 frame delay upon receiving measurement report
- ?? Std. dev. of CPICH measurement error: 0
- ?? CPICH measurement rate: once per 3.33 ms (sampling is 0.67ms, IIR filter sampled once per 3.33ms using IIR filter with coefficient of 0.3 (new data weighted by 0.7))
- ?? CPICH measurement report error rate: 0 %
- ?? Frame length for fast HARQ: 3.33 ms
- ?? Fast HARQ feedback error rate: 0%
- ?? Channel Model: 3kph, single Rayleigh ray with 0.98 fraction of recovered power
- ?? STTD enabled.
- ?? Maximum C/I scheduler (see [2])
- ?? Modified ETSI Call model (see [2])
- ?? No implementation loss (Note [4] had implementation loss of 1.5dB)
- ?? Throughput measurements are over the entire two-ring system and the center cell.

**Basic system level parameters:**
The basic system level simulation parameters are listed in Table B1 [2] below.

*Table B1. Basic system level simulation assumptions.*

| Parameter | Explanation/Assumption | Comments |
|---|---|---|
| Cellular layout | Hexagonal grid, 3-sector sites | 19 sites |
| Site to Site distance | 2800 m | |
| Antenna pattern | As proposed in [4] | Only horizontal pattern specified |
| Propagation model | $L = 128.1 + 37.6\ Log_{10}(R)$ | R in kilometres |
| CPICH power | -10 dB | |
| Other common channels | - 10 dB | |
| Power allocated to HSDPA transmission, including associated signaling | Max. 70% of total cell power | |
| Slow fading | Similar to UMTS 30.03, B 1.4.1.4 | |
| Std. deviation of slow fading | 8.0 dB | |
| Correlation between sectors | 1.0 | |
| Correlation between sites | 0.5 | |
| Correlation distance of slow fading | 50 m | See D,4 in UMTS 30.03. |
| Carrier frequency | 2000 MHz | |
| BS antenna gain | 14 dB | |
| UE antenna gain | 0 dBi | |
| UE noise figure | 9 dB | |
| Max. # of retransmissions | 15 | Retransmissions by fast HARQ |
| Fast HARQ scheme | Chase combining | Dual stop-and-wait |
| BS total Tx power | 42.3 dBm | |
| Active set size | 3 | Maximum size |
| Specify Fast Fading model | Jakes spectrum | Generated by Filter approach |