R1-062598 Uplink Distributed Transmissions

Agenda Item: 6.3.2

Summary (Slide 1 of 2)

- **Distributed transmission performance is very dependent on the UL RS multiplexing scheme**
  - **Minimum RS Bandwidth which drives the GCL/CAZAC length and # of sequences**
  - **Multiplexing of sounding RS and Data demodulation RS**
- **Four potential pilot structures are considered in R1-061720**
- **Options based on selective use of a LB for sounding**
  - **Option 1a: FDM with minimum data demodulation RS BW = RB BW for 1 RB allocation (see slides 7-9)**
    - Pilot RPF=1 on all SBs, RS sequence length of 6
    - Enables *Narrowband distributed transmission* (Data RPF=2 within a single RB) providing benefits of:
      - Better edge of cell performance than localized in power-limited case due to 3dB higher power/sub-carrier
      - Improved granularity to support smaller size packets
        - » Same effective number of data symbols as a 12 subcarrier x 0.5 ms allocation
      - Complete exploitation of the RS power for data demodulation
  - **Option 1b: Minimum data demodulation RS BW = 2 RB BW for 1 RB allocation (see slides 10-14)**
    - Pilot RPF=1 on all SBs, RS sequence length of 12
    - Performance of narrowband Distributed FDMA (spanning 2 RB) is better than that of localized FDMA
    - Also found that combining narrowband D-FDMA with intra-TTI Frequency Hopping performs better than L-FDMA with FH

Summary (Slide 2 of 2)

- **Broadband sounding separately multiplexed on short blocks**
  - **Option 2: Minimum data demodulation RS BW = 6 RB BW for 1 RB allocation (see slides 15-19)**
    - Pilot RPF=2 on all SBs, RS sequence length of 18
    - Sounding multiplexed on every other sub-carrier on the SBs
    - Distributed FDMA performance is better than localized FDMA with and without intra-TTI Frequency Hopping
    - Gains increase with larger frequency diversity channels such as GSM TU 12-ray channel
  - **Option 3: Hybrid of option 1a and option 2 (see slides 20-22)**
    - Benefits of Narrowband distributed transmission (Data RPF=2) within an RB similar to option 1a
- **Results for 1.25 MHz and 5 MHz sub-band D-FDMA compared with Option 1a L-FDMA in appendix (slides 24-26)**
  - **Gains for D-FDMA increase with SNR**
- **Frequency diversity gains of distributed FDMA can be enhanced with advanced receivers (MMSE + Decision-directed ISI cancellation)**
- **Distributed allocations should be used to achieve diversity scheduling when channel dependent scheduling is not possible due to lack of reliable CQI information at the Node-B (e.g., VoIP users, high mobility etc.)**

Simulation Assumptions

- **System Parameters**
  - **DFT-SOFDM parameters included in the EUTRA 3GPP SI Technical Report (TR)**

Item	**Value/Description**
Channel Bandwidth	5 MHz
Number of sub-carriers (LB/SB)	300/150
Sub-carrier spacing (LB/SB)	15/30 kHz
Cyclic prefix length	4.04 μs
Baud/Symbol duration (LB/SB)	66.67/33.33 μs
FFT size (LB/SB)	512/256
Modulation	QPSK, 16-QAM
Coding	R = ½, Turbo Max-log-MAP kernel
Channel	GSM TU, 15kph
Number of Rx Antennas	2

- **Half-length Short Blocks (SB) used for GCL pilot/reference signals**
- **Real channel estimation (MMSE)**
- **Linear MMSE Receiver**
- **Only a single active UE with different RB allocations / effective (Repetition factors) RPFs**
  - **RB = 12 sub-carriers for the duration of the 0.5ms sub-frame**
- **With and without Intra-TTI (TTI = 1ms) Frequency Hopping within a 1.25 MHz sub-band**

RB Allocations

- RBs (localized and distributed) allocated in multiples of 2 and 3 for efficient DFT implementation
  - Need to support only radix-2 and radix-3 FFTs
- For Sub-band = 1.25MHz (6 RBs)
  - # of RBs than can be allocated = 6, 3, 2, 1
- For Sub-band = 2.5MHz (12 RBs)
  - # of RBs than can be allocated = 12, 8, 6, 4, 3, 2, 1
- For Sub-band = 5MHz (24 RBs)
  - # of RBs than can be allocated = 24, 18, 16, 12, 8, 6, 4, 3, 2, 1

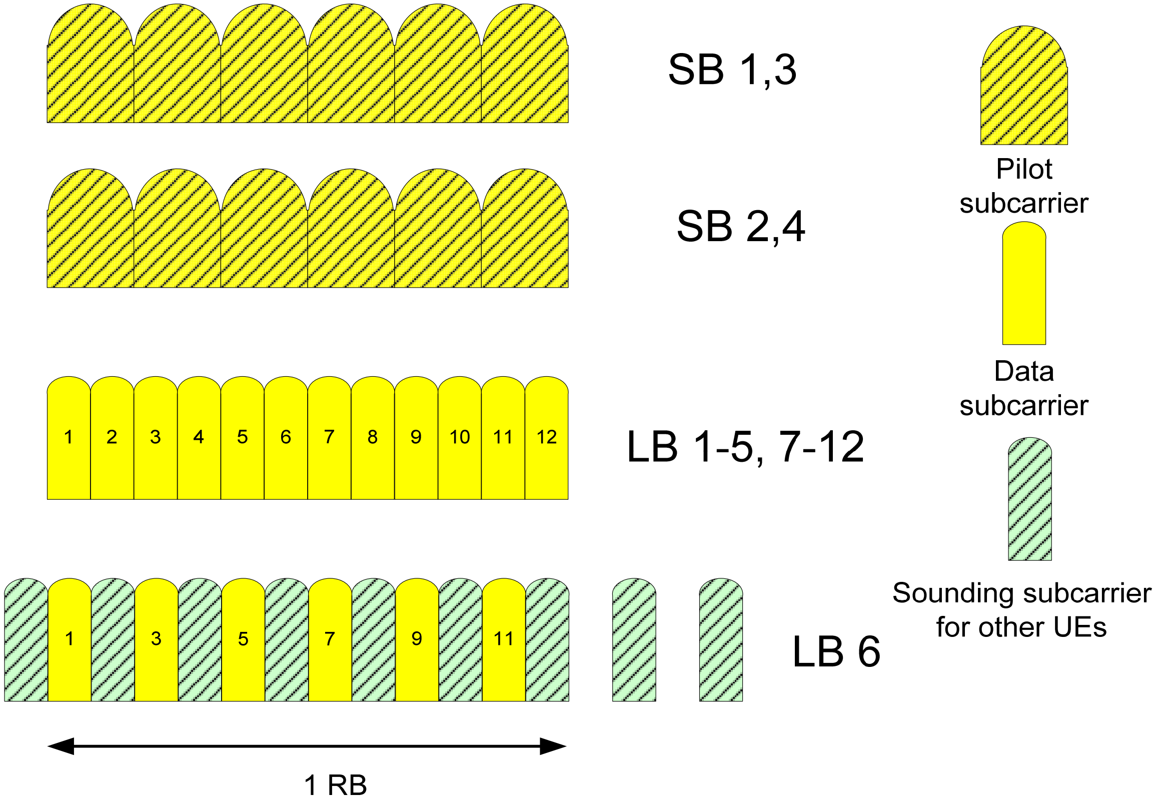
Distribution Transmissions

- Concern: Potential performance degradation due to frequency error and power differences between UEs
- However, with CDM RS or distributed sounding RS, any frequency error and power differences between UEs can severely degrade the channel estimator regardless of the data multiplexing method – localized or distributed
- Thus, small residual frequency error (fraction of a sub-carrier spacing) is desirable for CDM or distributed RS and data

Pilot Option 1a: FDM Pilots on all SBs

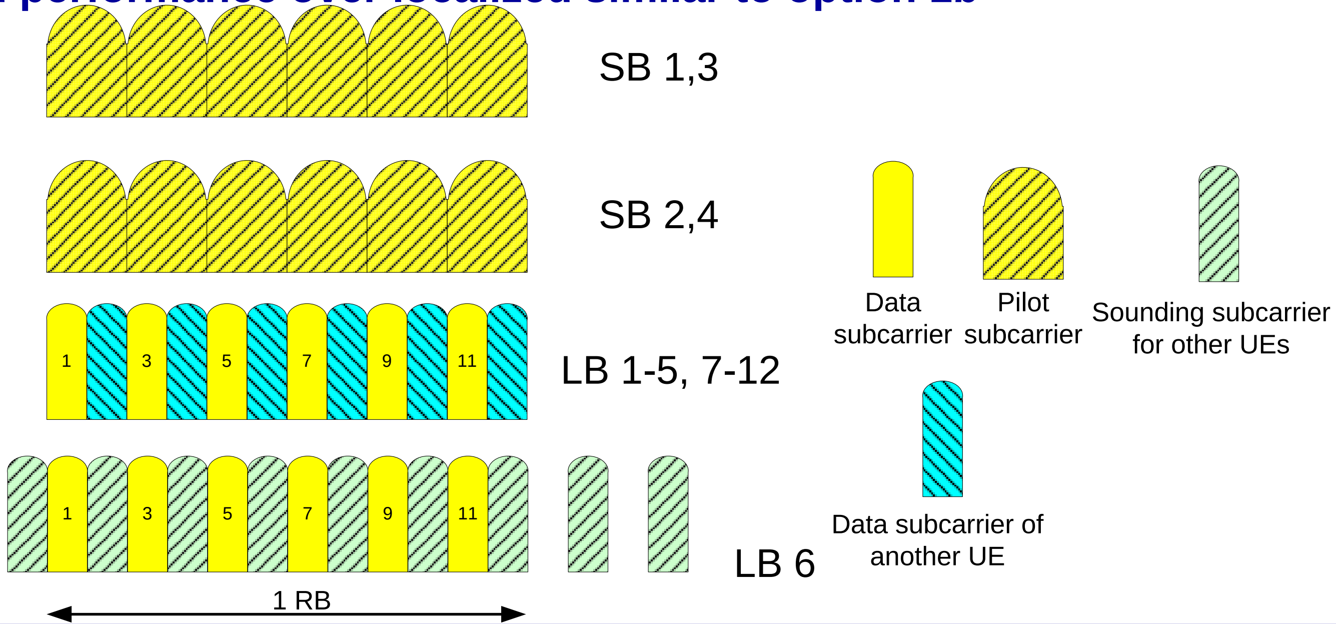
Pilot Option 1a: FDM on all SBs (Slide 1 of 2)

- **FDM with minimum data demodulation RS BW = RB BW for 1 RB allocation**
- **Pilot RPF=1 on all SBs**
- **Localized Data: Localized FDM (Data RPF = 1)**



Pilot Option 1a: Narrowband Distributed Data (Slide 2 of 2)

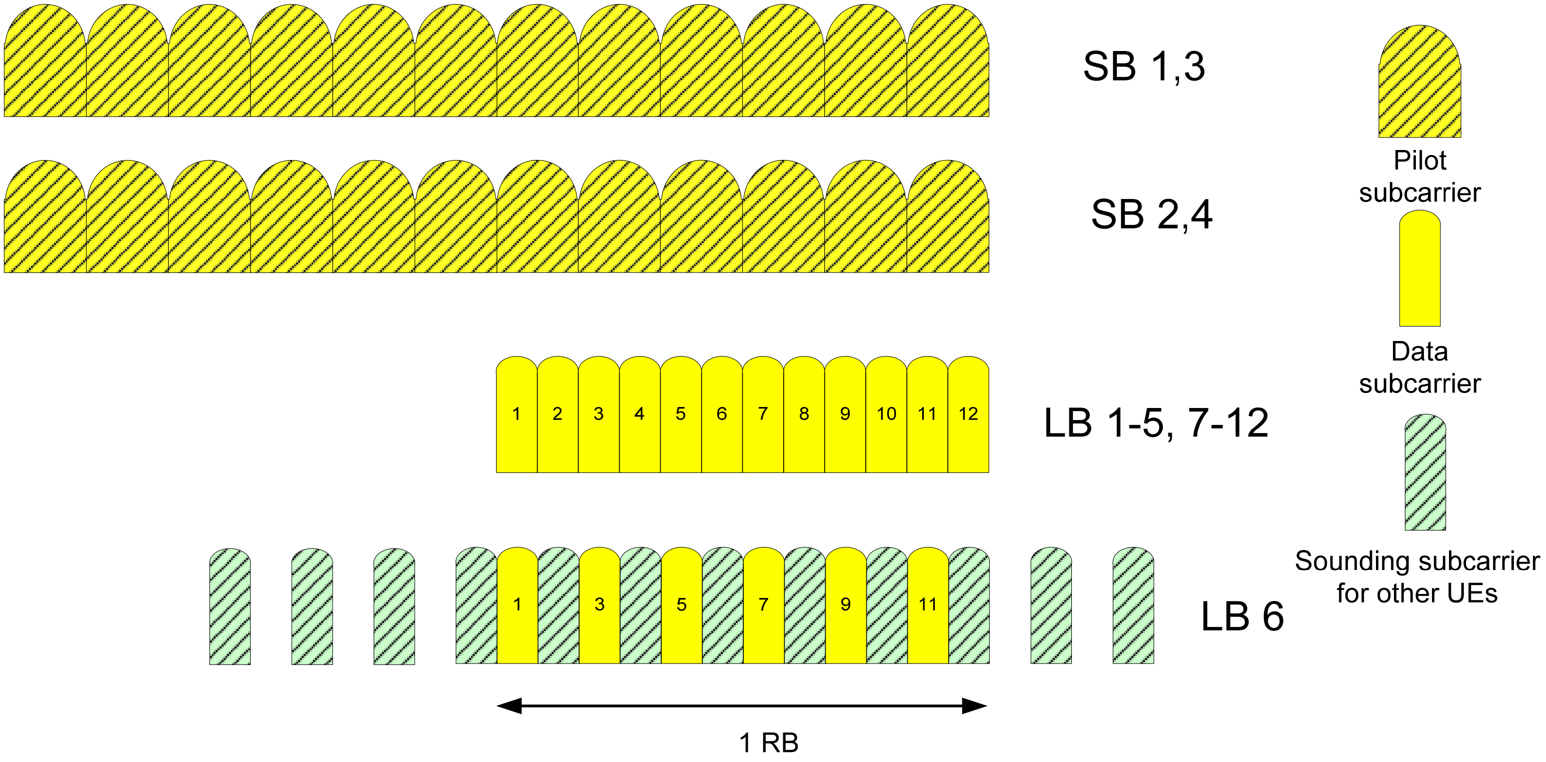
- **Data RPF=2 within a single RB, 1 ms TTI**
- **Benefits:**
  - **Better edge of cell performance than localized in power-limited case due to 3dB higher power/data-sub-carrier**
  - **Improved granularity to support smaller size packets**
    - Same effective number of data symbols as a 12 subcarrier x 0.5 ms allocation
  - **Complete exploitation of the RS power for data demodulation**
- **Can combine Distributed transmission and Intra-TTI Frequency Hopping with improved performance over localized similar to option 1b**



Performance comparison of Distributed and Localized FDMA with Pilot Option 1b

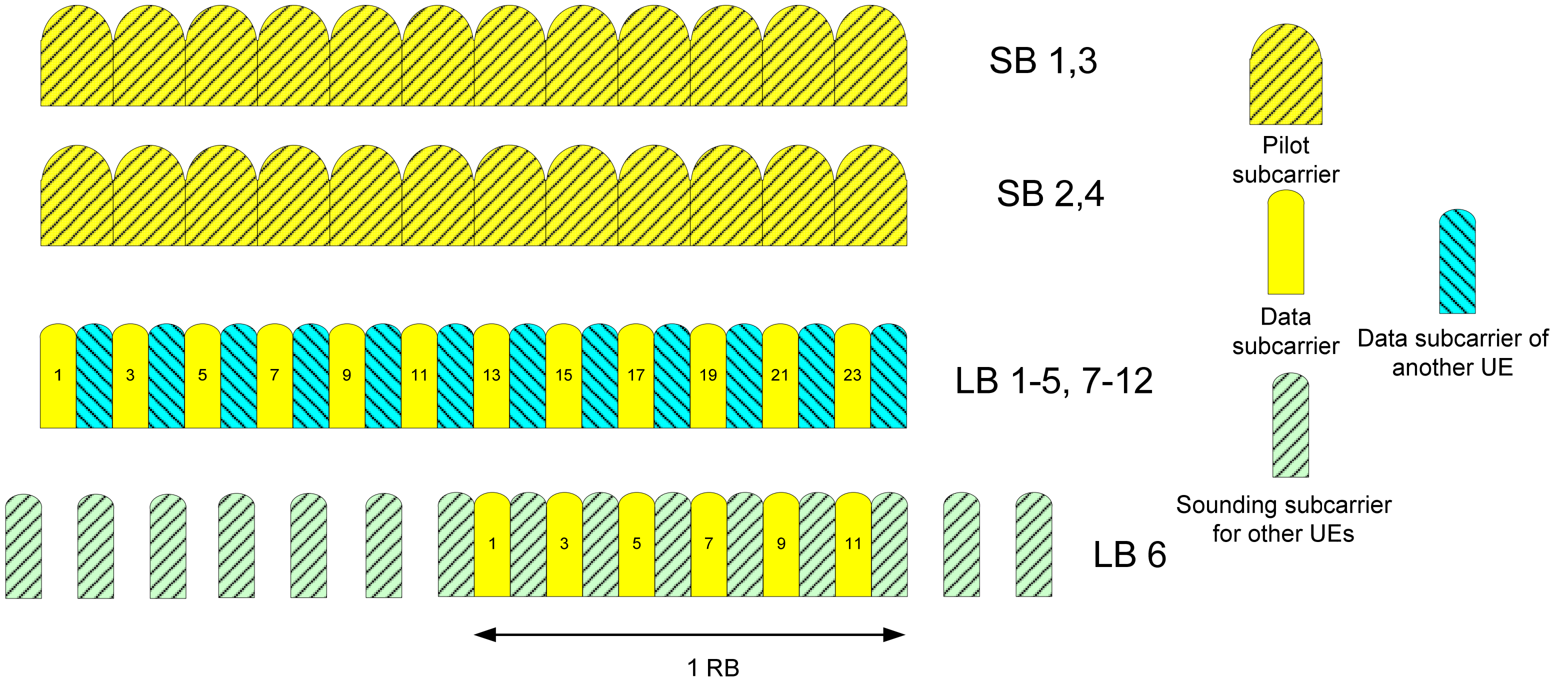
Pilot Option 1b: 2RB RS BW on all SBs (Slide 1 of 2)

- Minimum data demodulation RS BW = 2RB BW
- Pilot RPF=1 on all SBs
- For 1 RB allocation
  - Localized Data (Data RPF=1)



Pilot Option 1b: 2RB RS BW on all SBs (Slide 2 of 2)

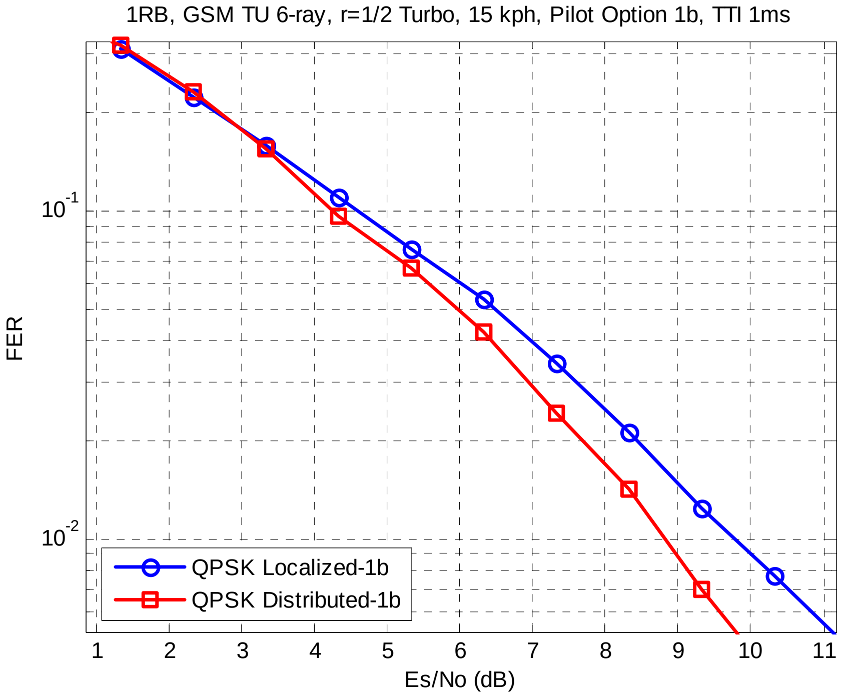
- **Narrowband Distributed Data transmission for 1 RB allocation**
  - **Data RPF=2 over 2 RBs**
  - **Complete exploitation of the 2RB RS power for data demodulation**
  - **Benefits from combining Distributed transmission and Intra-TTI Frequency Hopping as shown in slide 14**



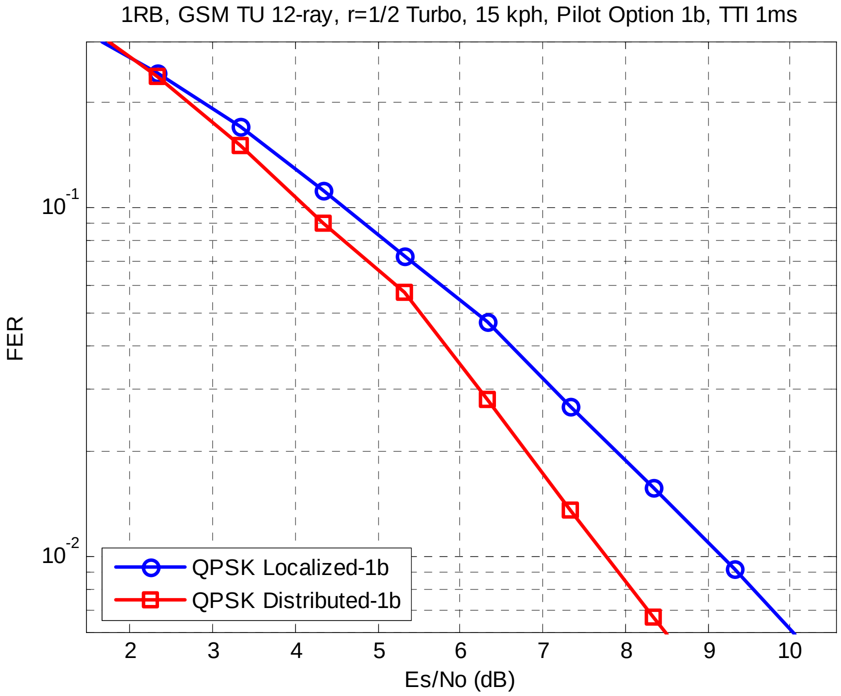
GSM TU, Pilot Option 1b, MMSE Receiver

- TTI = 1ms, 2RB RS BW, No Intra-TTI Hopping
- Allocation is two consecutive (in time) resource blocks within a TTI

1 RB Allocation, TU 6-ray



1 RB Allocation, TU 12-ray

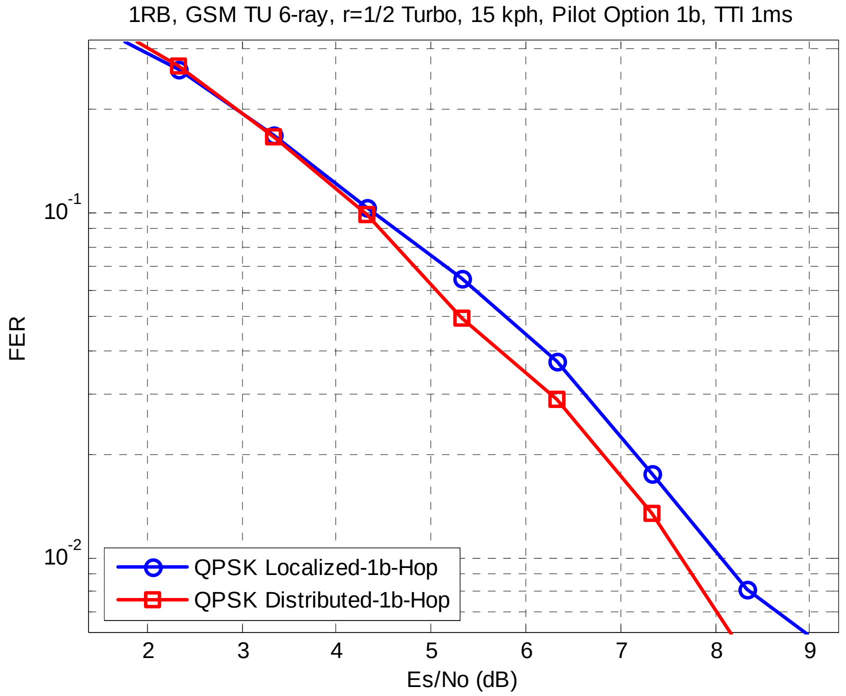


- D-FDMA performance better than L-FDMA
  - Gains increase with larger frequency diversity GSM TU 12-ray channel
- Performance gains of ~0.3/0.5dB @ 10% FER and ~1/1.5dB @ 1% FER for GSM TU 6/12-ray channel
- Results suggest that Distributed with data RPF=2 over 2RBs can also be beneficial for 1RB allocation with channel dependent scheduling

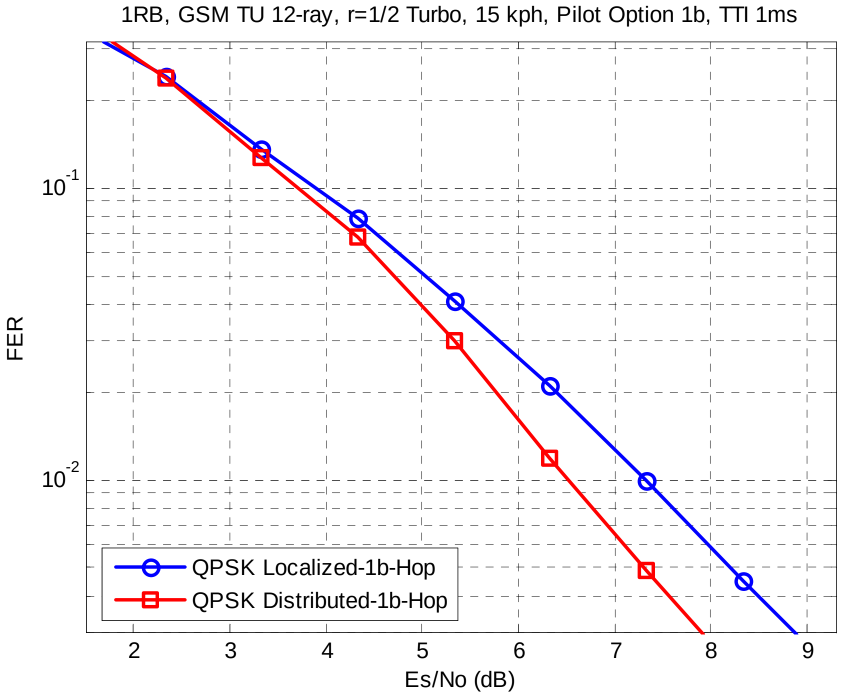
GSM TU, Pilot Option 1b, MMSE Receiver

- **TTI = 1ms, 1.25MHz sub-band, Intra-TTI Hopping**
- **Allocation is two consecutive (in time) resource blocks within a TTI**

1 RB Allocation, TU 6-ray



1 RB Allocation, TU 12-ray

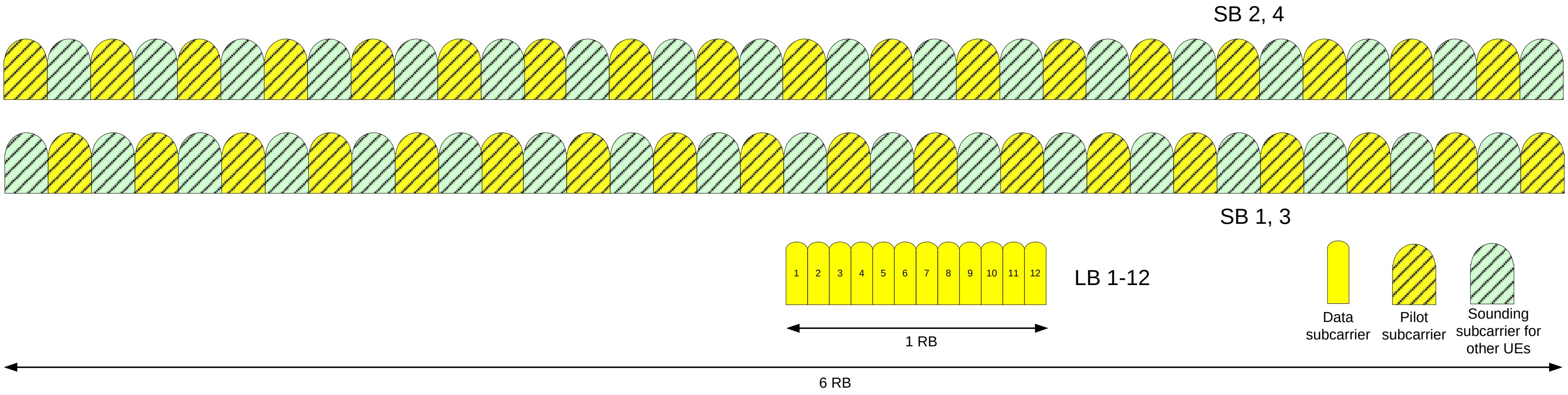


- **With Intra-TTI Hopping, D-FDMA performance better than L-FDMA w/FH**
  - **Gains increase with larger frequency diversity GSM TU 12-ray channel**
- **Performance gains of ~0.1/0.2dB @ 10% FER and ~0.4/0.8dB @ 1% FER for GSM TU 6/12-ray channel**

Performance comparison of Distributed and Localized FDMA with Pilot Option 2

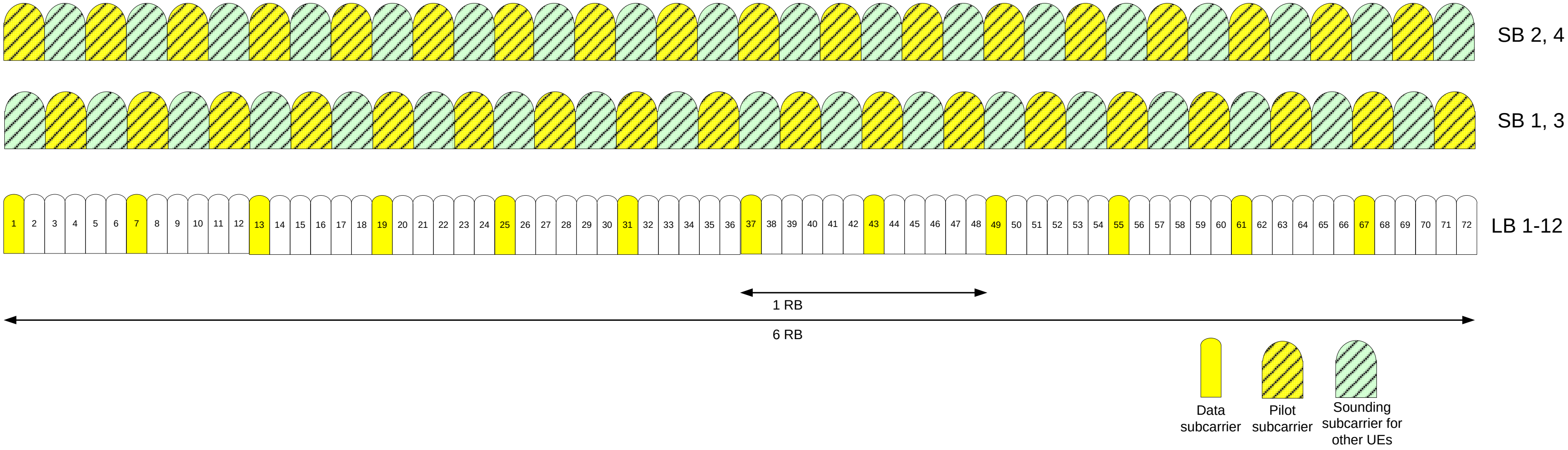
Pilot Option 2: Hybrid FDM/CDM, 6RB BW (Slide 1 of 2)

- Minimum data demodulation RS BW = 6 RB BW
  - Pilot RPF=2 on all SBs
  - Sounding multiplexed on every other sub-carrier on the SBs
- Staggering of the pilot combs
- For 1 RB allocation
  - Localized Data: Localized FDM (Data RPF=1)



Pilot Option 2: Hybrid FDM/CDM, 6RB BW (Slide 2 of 2)

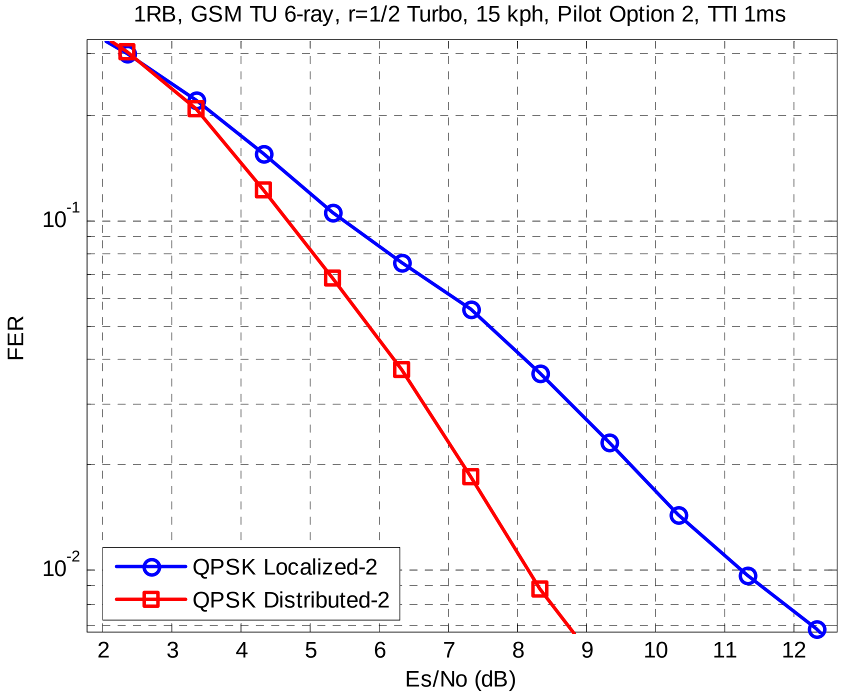
- **For 1 RB allocation**
  - **Distributed Data: Data RPF=6 within the data demodulation RS BW of 6 RBs**
    - Complete exploitation of the 6RB RS power for data demodulation



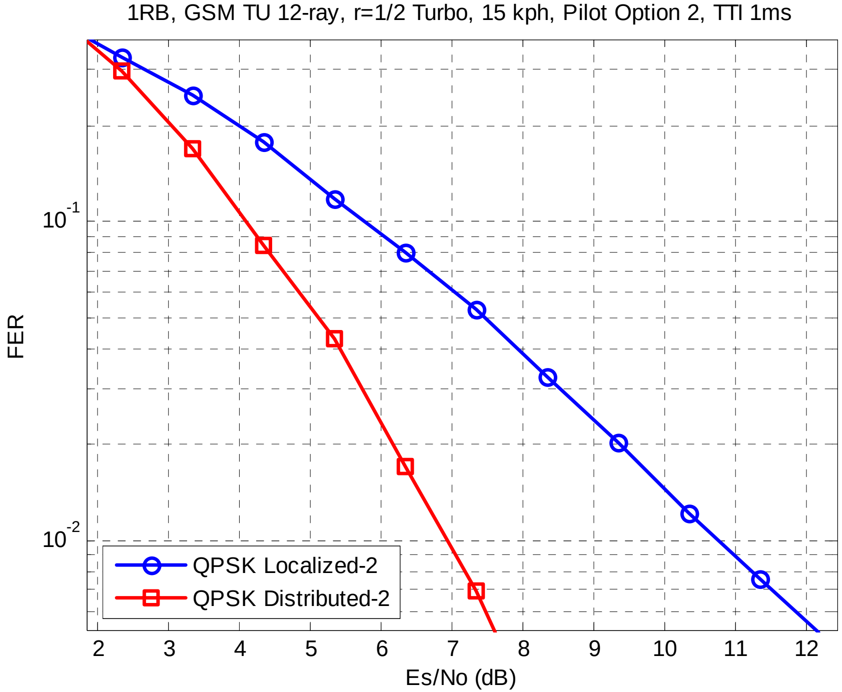
GSM TU, Pilot Option 2, MMSE Receiver

- TTI = 1ms, 1.25MHz sub-band, No Intra-TTI Hopping
- Allocation is two consecutive (in time) resource blocks within a TTI

1 RB Allocation, TU 6-ray



1 RB Allocation, TU 12-ray

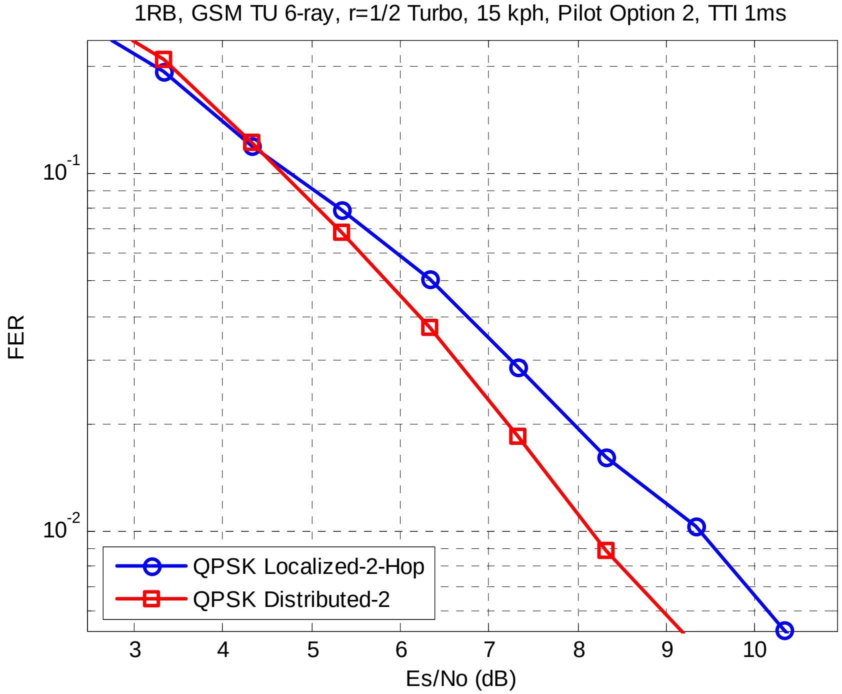


- D-FDMA (1.25MHz sub-band) performance better than L-FDMA
  - **Better performance with larger frequency diversity GSM TU 12-ray channel**
- Performance gains of
  - **~0.8dB @ 10% FER and >3dB @ 1% FER for GSM TU 6-ray channel**
  - **~1.75dB @ 10% FER and >3dB @ 1% FER for GSM TU 12-ray channel**

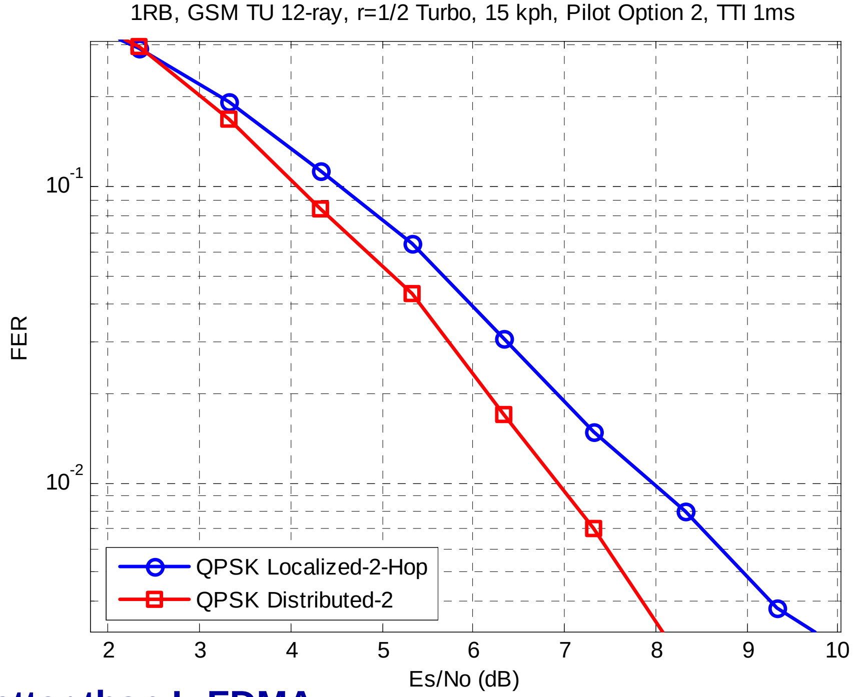
GSM TU, Pilot Option 2, MMSE Receiver

- TTI = 1ms, 1.25MHz sub-band, Localized allocation with Intra-TTI Hopping
- Allocation is two consecutive (in time) resource blocks within a TTI

1 RB Allocation, TU 6-ray



1 RB Allocation, TU 12-ray

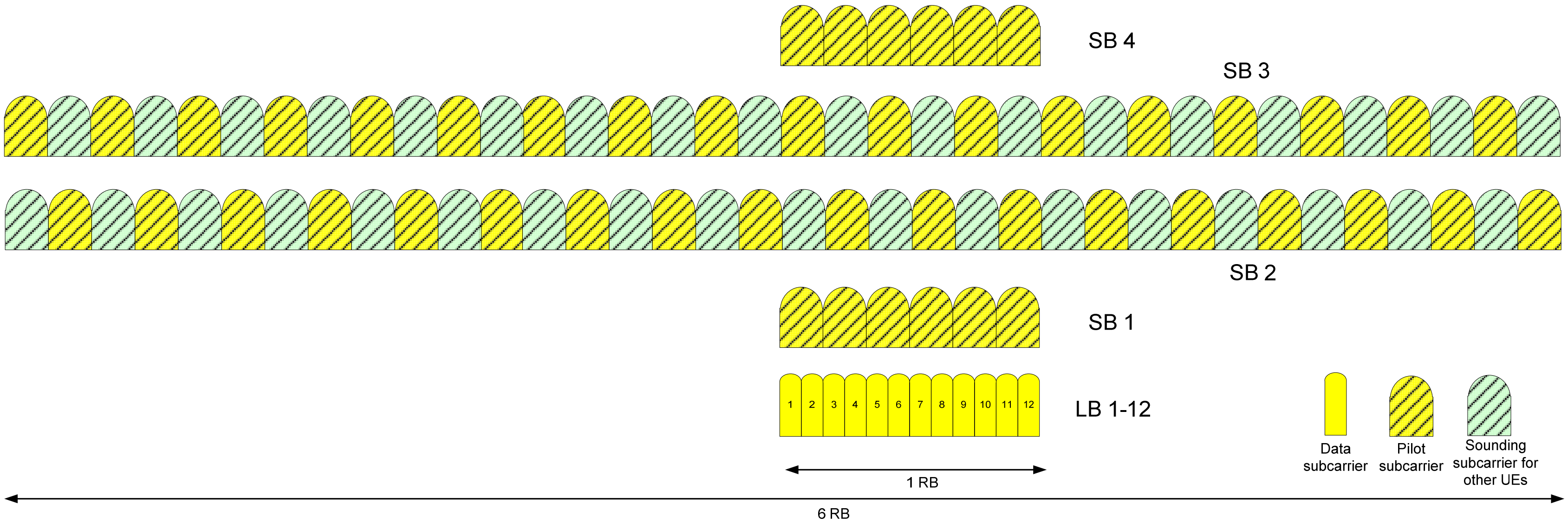


- D-FDMA (1.25MHz sub-band) performance better than L-FDMA
  - Better performance with larger frequency diversity GSM TU 12-ray channel
- Performance gains of
  - ~0.1dB @ 10% FER and ~1dB @ 1% FER for GSM TU 6-ray channel
  - ~0.5dB @ 10% FER and ~1dB @ 1% FER for GSM TU 12-ray channel

Pilot Option 3

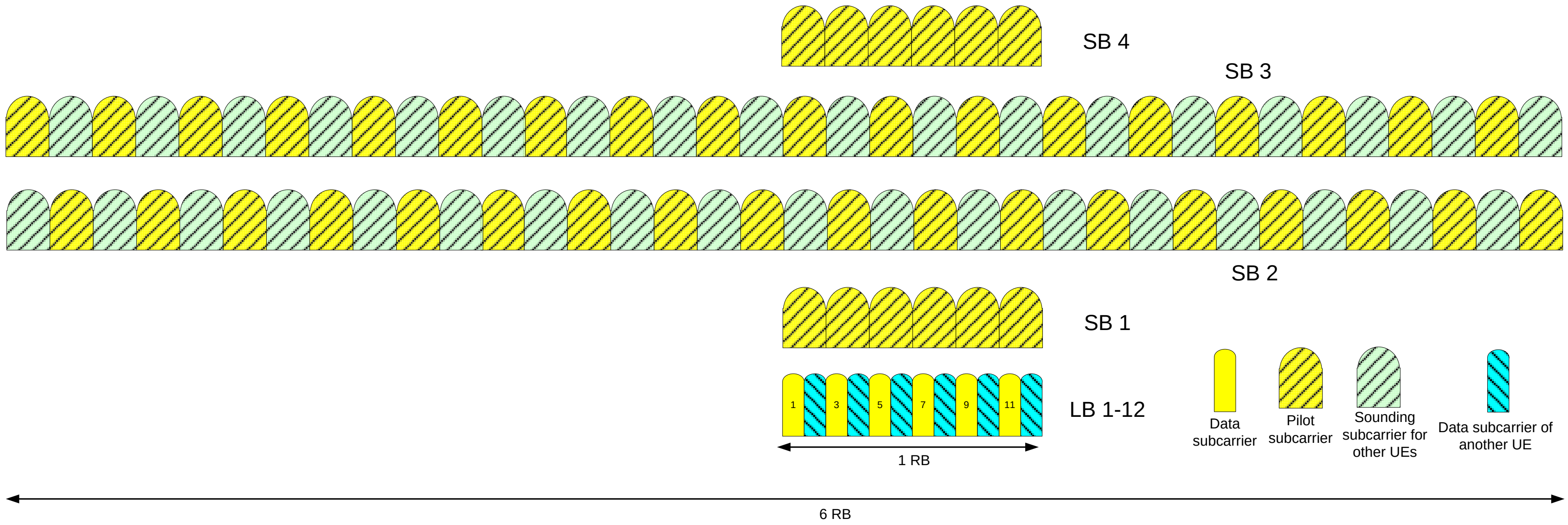
Pilot Option 3: FDM on SB1, SB3, Hybrid FDM/CDM on SB2, SB4

- FDM with minimum data demodulation RS BW = RB BW
- Localized FDM on SB1, SB4 like Option 1a
  - FDM with minimum data demodulation RS BW = RB BW
  - Pilot RPF=1
- Hybrid FDM/CDM on SB2, SB4 like Option 2
  - Minimum data demodulation RS BW = 6 RB BW
  - Pilot RPF=2
  - Staggering of the pilot combs
  - Sounding multiplexed on every other sub-carrier on SB2 and SB3
- Localized Data: Localized FDM (Data RPF = 1)



Pilot Option 3: Distributed Data

- **Similar to Option 1a**
- **Data RPF=2 within an RB for two consecutive (in time) resource blocks within a TTI**
- **Benefits:**
  - **Better edge of cell performance than localized in power-limited case due to 3dB higher power/data-sub-carrier**
  - **Improved granularity to support smaller size packets**
    - Same effective number of data symbols as a 12 subcarrier x 0.5 ms allocation
  - **Complete exploitation of the RS power for data demodulation**
- **Can combine Distributed transmission with Intra-TTI Frequency Hopping similar to option 1b**

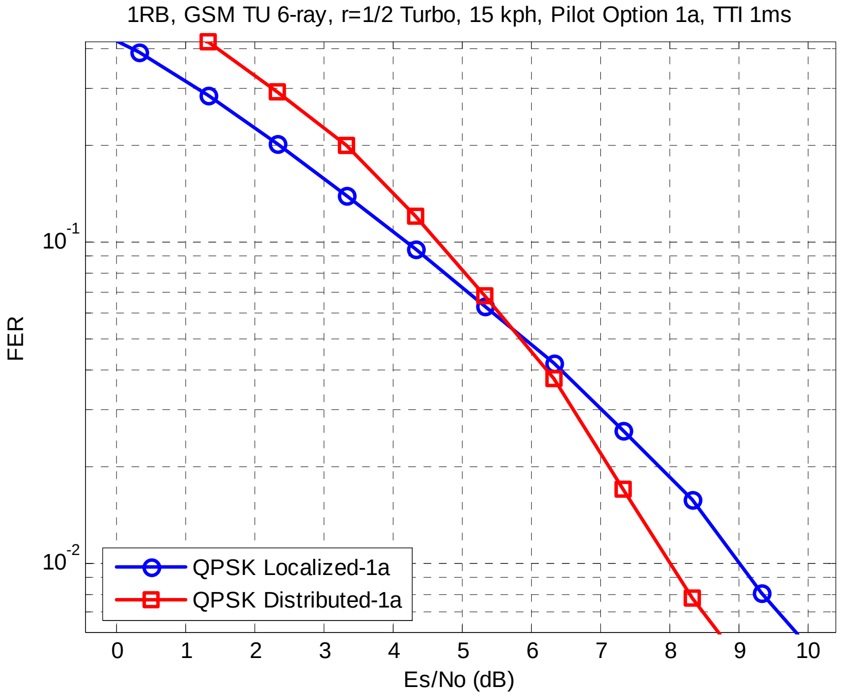


Appendix: Option 1a L-FDMA compared with 1.25 MHz and 5 MHz sub-band D-FDMA

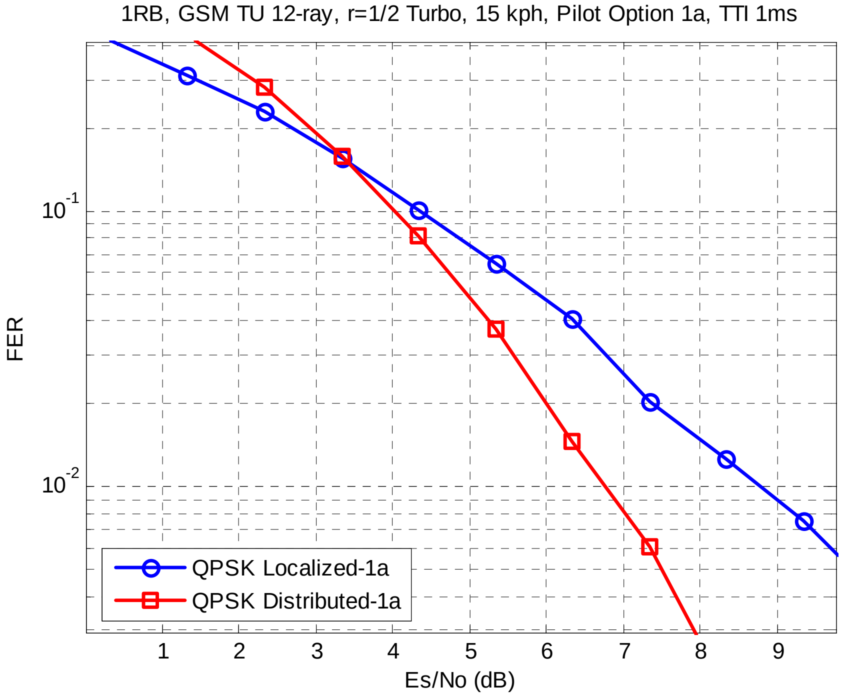
GSM TU, FDM Pilots, MMSE Receiver

- TTI = 1ms, 1.25MHz sub-band, No Intra-TTI Hopping
- Allocation is two consecutive (in time) resource blocks within a TTI

1 RB Allocation, TU 6-ray



1 RB Allocation, TU 12-ray

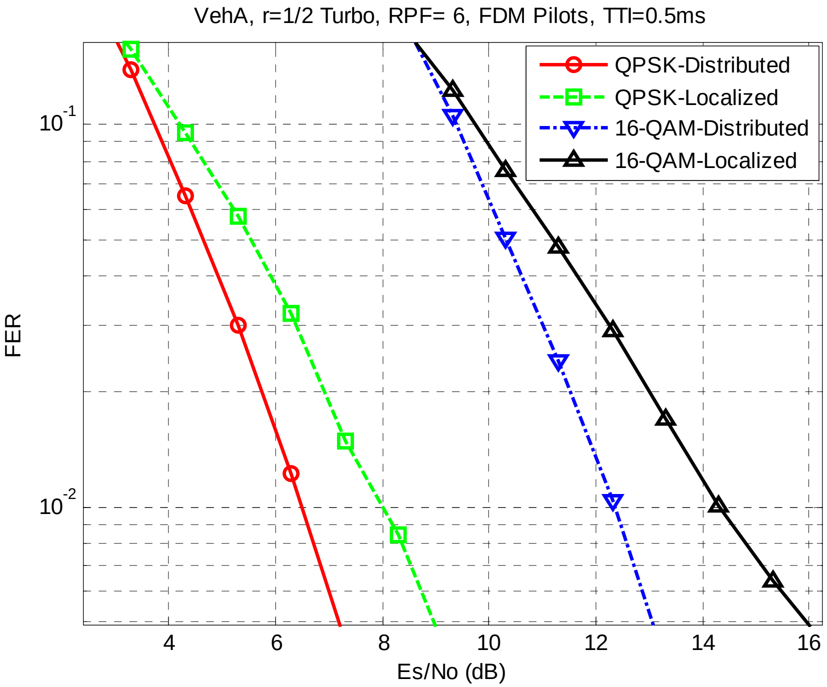


- D-FDMA (1.25MHz sub-band) performance similar or better than L-FDMA
  - Similar performance at higher FER (10%)
  - Better performance at lower FERs
  - Better performance with larger frequency diversity GSM TU 12-ray channel
- Performance gains of ~0.4dB @ 10% FER and ~2dB @ 1% FER for GSM TU 12-ray channel

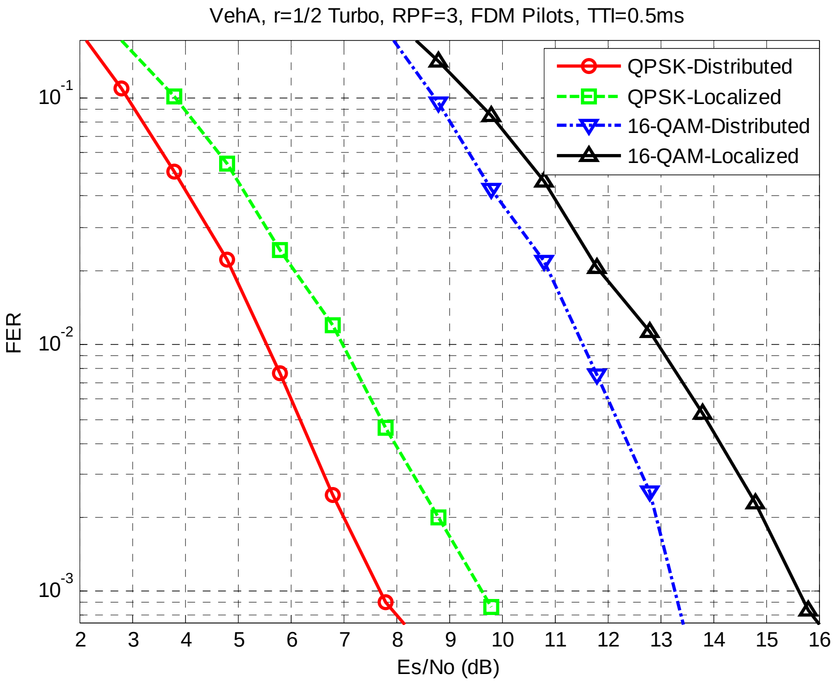
Vehicular A, FDM Pilots, MMSE Receiver

- TTI = 1ms, 5MHz sub-band, No Intra-TTI Hopping
- Allocation is multiple resource block (sub-frame) within a TTI

4 RB allocation


VehA, r=1/2 Turbo, RPF= 6, FDM Pilots, TTI=0.5ms

8 RB allocation

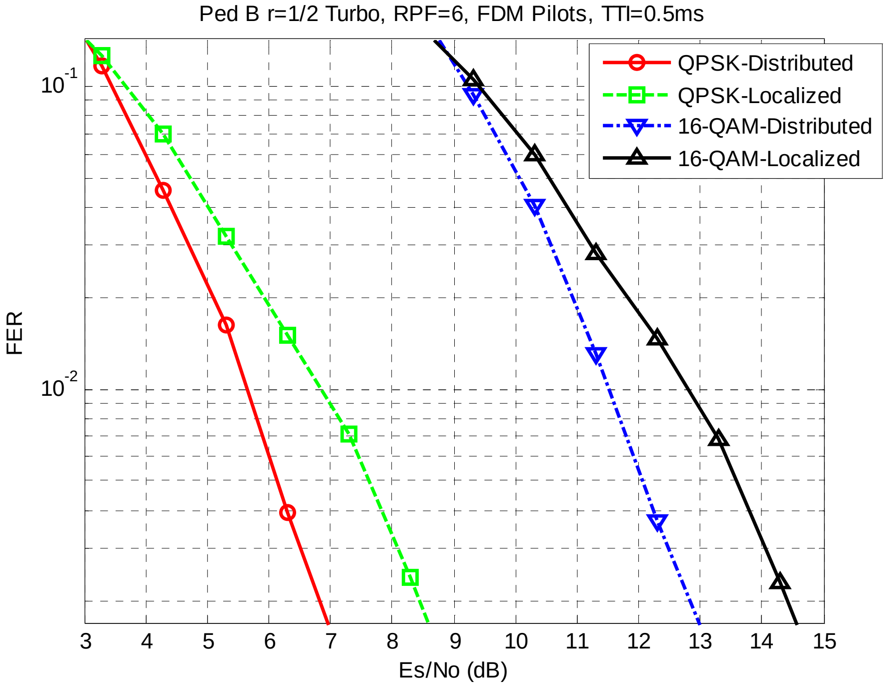

VehA, r=1/2 Turbo, RPF=3, FDM Pilots, TTI=0.5ms

- Distributed FDMA (5MHz sub-band) out performs localized FDMA due to larger frequency diversity
- Performance gains of ~0.4dB @ 10% and ~1.5-2dB @ 1% FER for 4RB allocation
- Performance gains of ~0.7dB @ 10% and ~1.5dB @ 1% FER for 8 RB allocation
- D-FDMA performance gains increases for lower FER targets

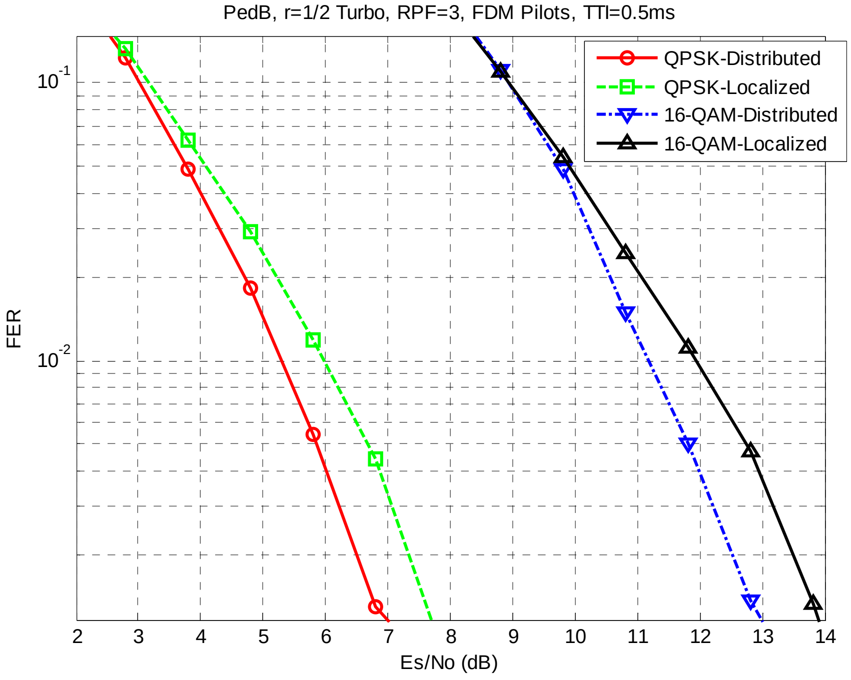
Ped B, FDM Pilots, MMSE Receiver

- TTI = 1ms, 5MHz sub-band, No Intra-TTI Hopping
- Allocation is multiple resource block (sub-frame) within a TTI

4 RB allocation



8 RB allocation



- D-FDMA (5MHz sub-band) performance similar or better than L-FDMA
  - Similar performance at higher FER (10%)
  - Better performance at lower FERs
- Performance gains of ~1.25dB @ 1% FER for 4RB and ~0.75dB @ 1% FER for 8RB allocations