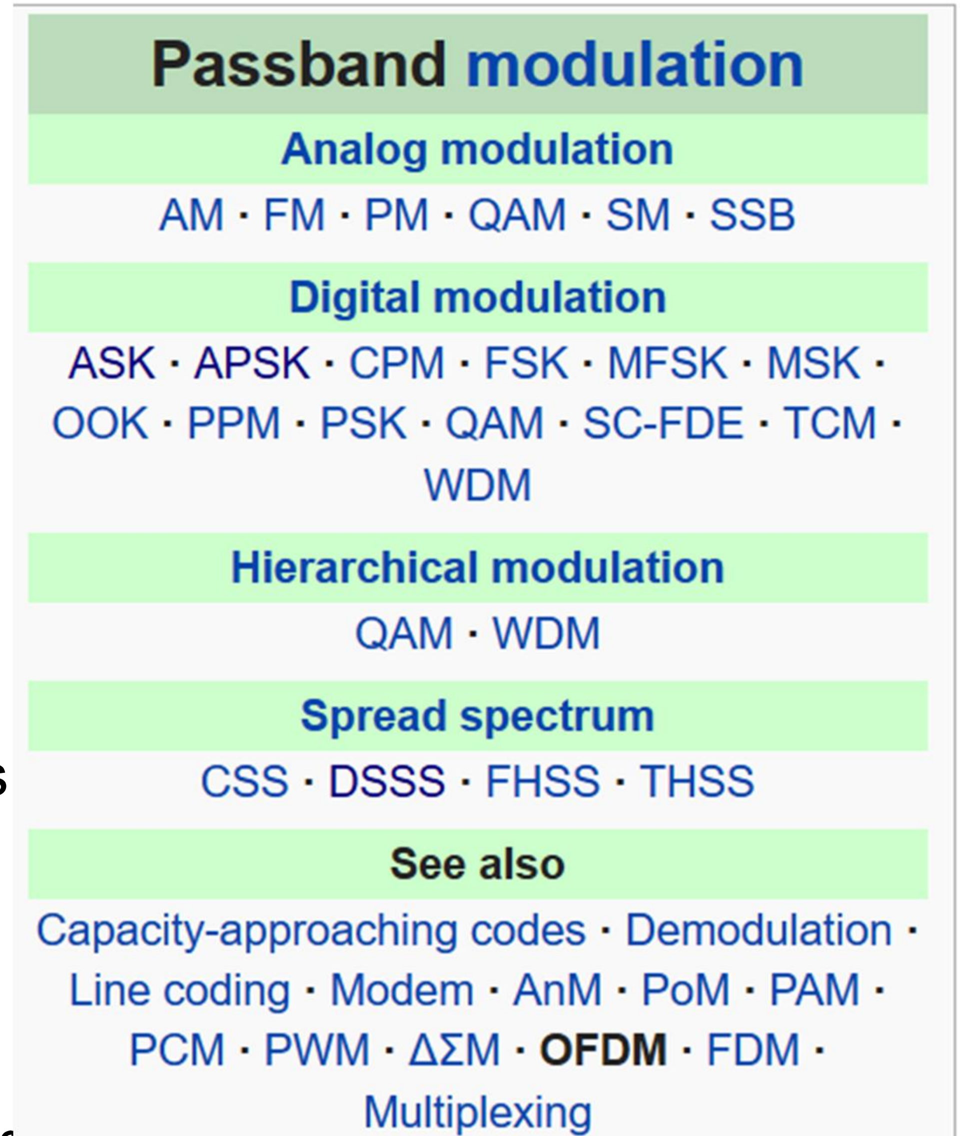
Digitalni sistemi prenosa

Profesor dr Miroslav Lutovac

Orthogonal frequency-division multiplexing

- Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies
- OFDM has developed into a popular scheme for wideband digital communication, used in applications such as
  - digital television
  - audio broadcasting
  - DSL internet access
    (Digital subscriber line, digital subscriber loop)
  - wireless networks
  - power line networks
  - 4G mobile communications

- In coded orthogonal frequency-division multiplexing (COFDM), forward error correction (convolutional coding) and time/frequency interleaving are applied to the signal being transmitted
- This is done to overcome errors in mobile communication channels affected by multipath propagation and Doppler effects
- In practice, OFDM has become used in combination with such coding and interleaving, so that the terms COFDM and OFDM co-apply to common applications.



- Duplexing Technique

  FDD/TDD

A duplex communication system is a point-to-point system composed of two or more connected parties or devices that can communicate with one another in both directions.

Time-division duplexing (TDD), Frequency-division duplexing (FDD)

- Multiple Access Method

  TDMA/OFDMA

  OFDM Symbols allocated by TDMA

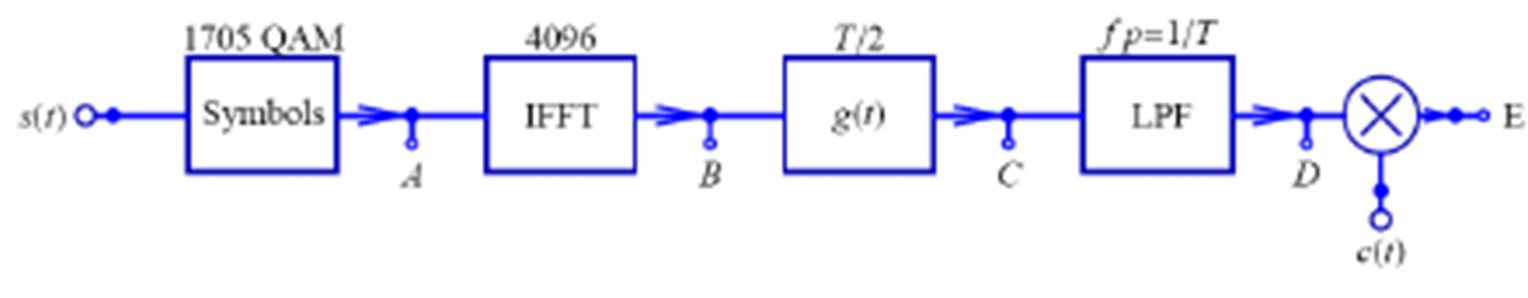
  Sub-Carriers

channel access method or multiple access method allows several terminals connected to the same multi-point transmission medium to transmit over it and to share its capacity

- Diversity

  Frequency, Time, Code (CPE and BS), Space Time Coding, Antenna Array

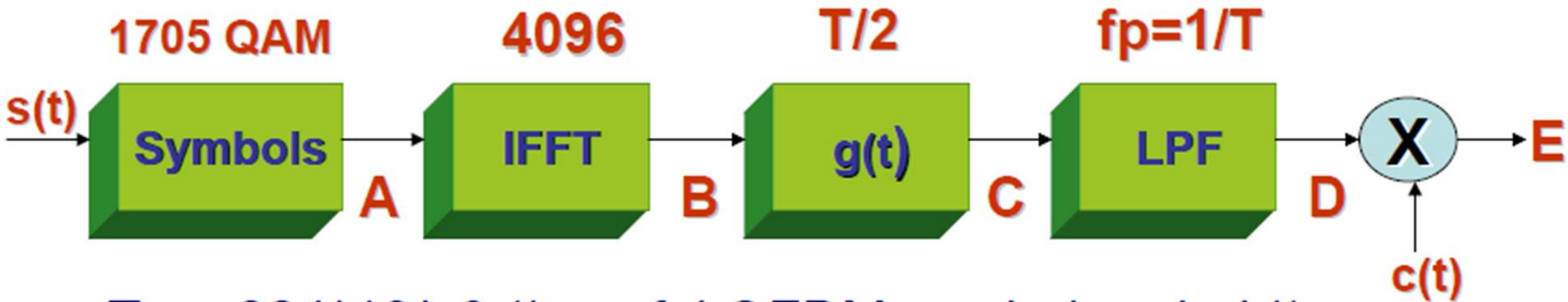
Method for improving the reliability of a message signal by using two or more communication channels with different characteristics.



Orthogonal Frequency Division Multiplexing
Digital Video Broadcasting

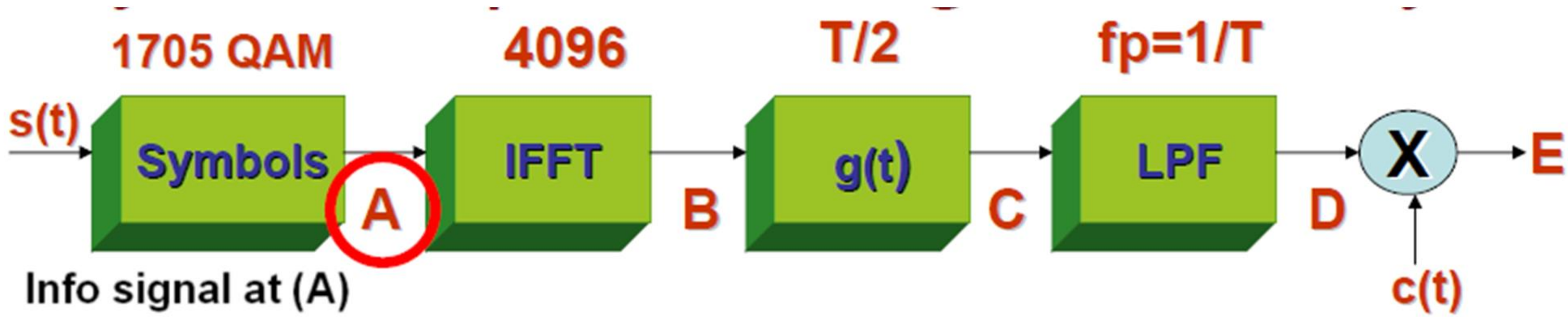
OFDM DVB Transmitter

Any block is realized using symbolic processing



- Tu = 224*10^-6;(* useful OFDM symbol period *)
- T = Tu/2048; (* baseband elementary period *)
- G = 0; (* choice of 1/4,1/8,1/16,and 1/32 *)
- Ts = G*Tu + Tu;(* total OFDM symbol period *)

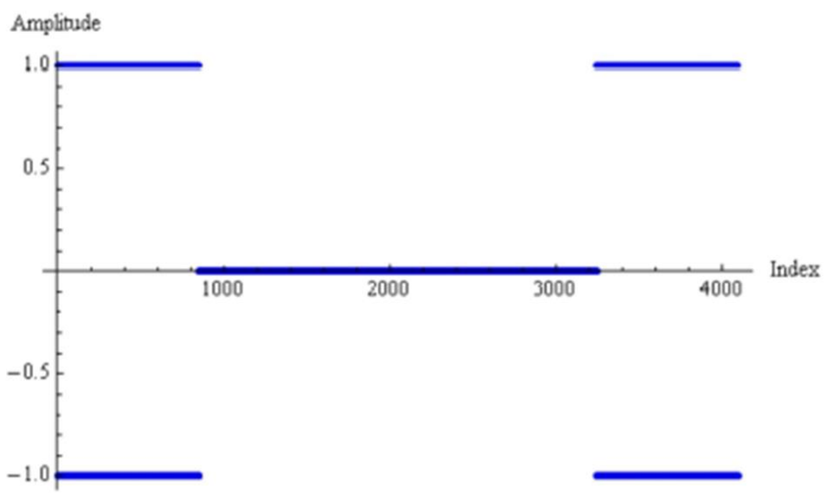
- FS = 4096; (* IFFT/FFT length *)
- q=10;(*carrier period to elementary period ratio*)
- fc = q*1/T;(* carrier frequency *)
- Rs = 4*fc;(* simulation period *)



Info signal at (A)

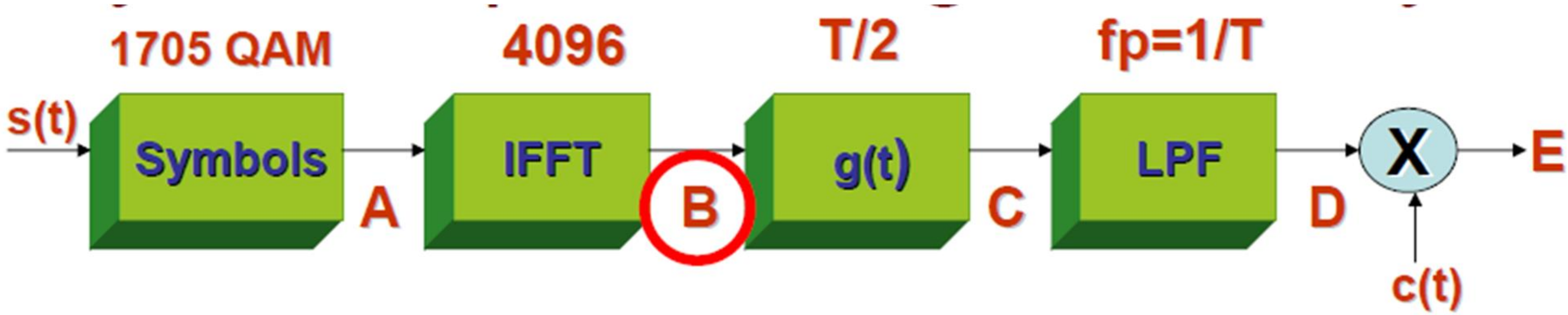
```
a = -1 + 2 an1 + I (-1 + 2 an2);
info = ListToSequence[Table[0, {i, 1, FS}]];
info[[1 ;; M / 2]] = a[[1 ;; M / 2]];
info[[-M / 2 ;; -1]] = a[[M / 2 + 1 ;; M]];

SequencePlot[Re[info][[1 ;; FS]], StemPlot → False, Joined → False,
  AxesLabel → {"Index", "Amplitude"}];
```



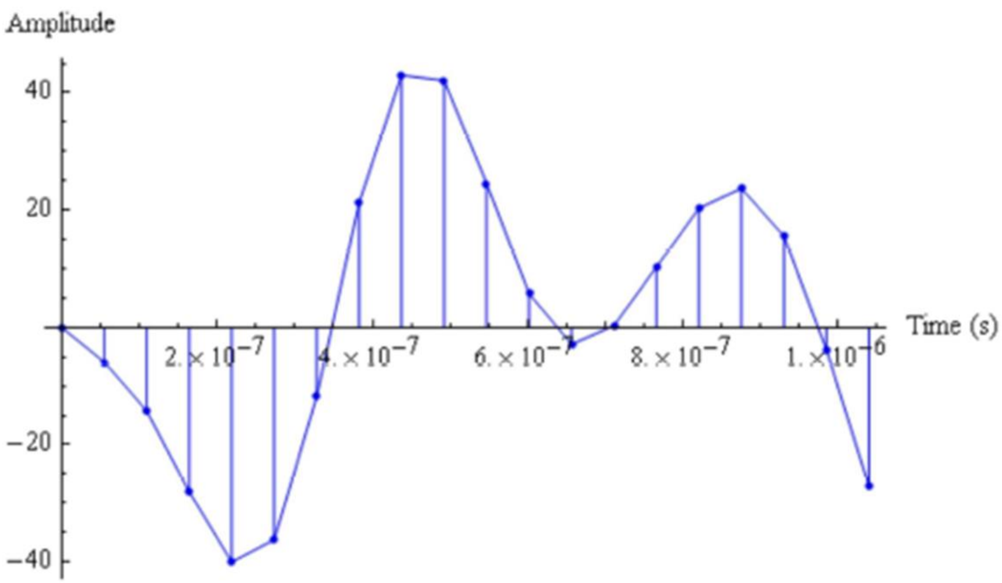
- The input signal *a* consists 1705 symbols

11

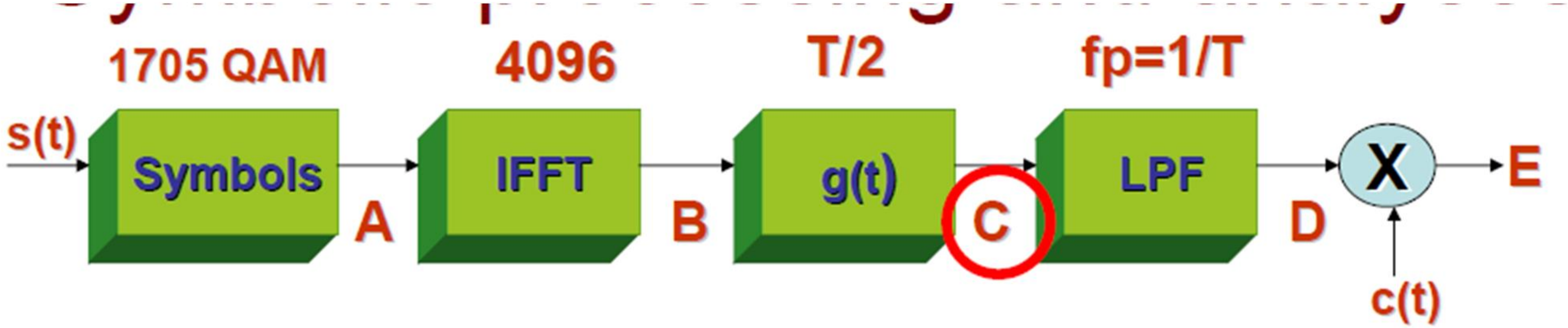


- **Carriers Inphase**

```
SequencePlot[Re[carriers][[1 ;; 20]], Joined → True, SequenceSamplingFrequency → 2 / T,
 AxesLabel → {"Time (s)", "Amplitude"}]
```

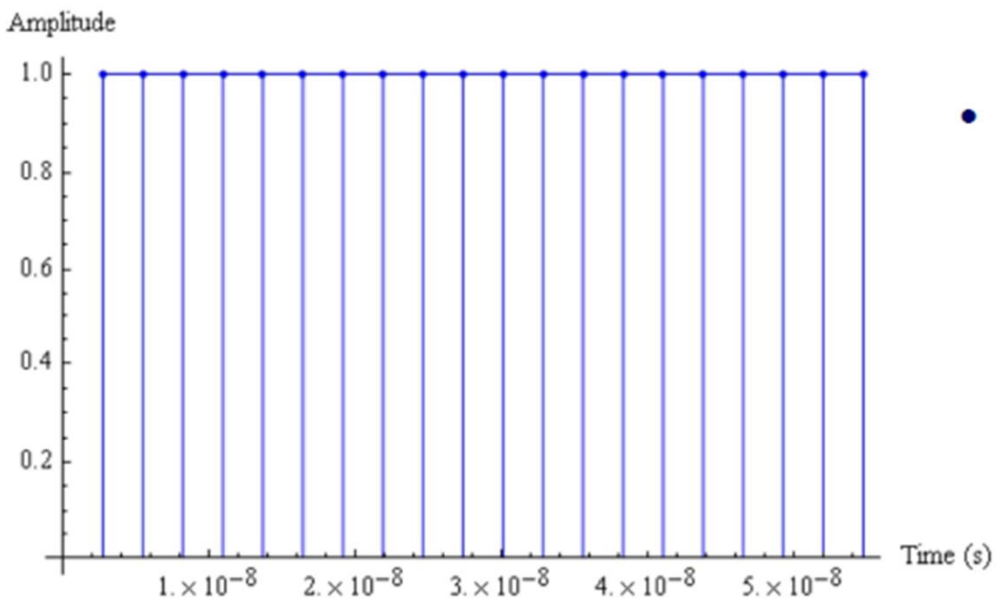


- The signal at **B** is computed using IFFT

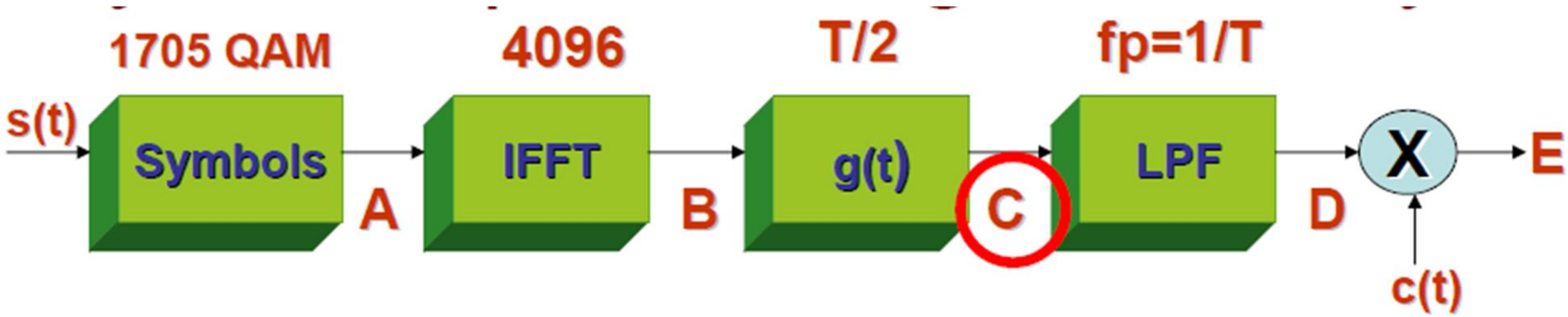


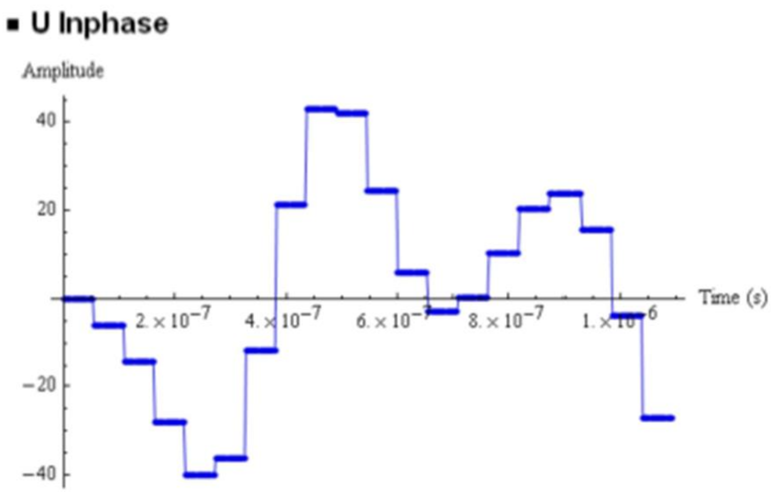
- **Pulse shape g (t)**

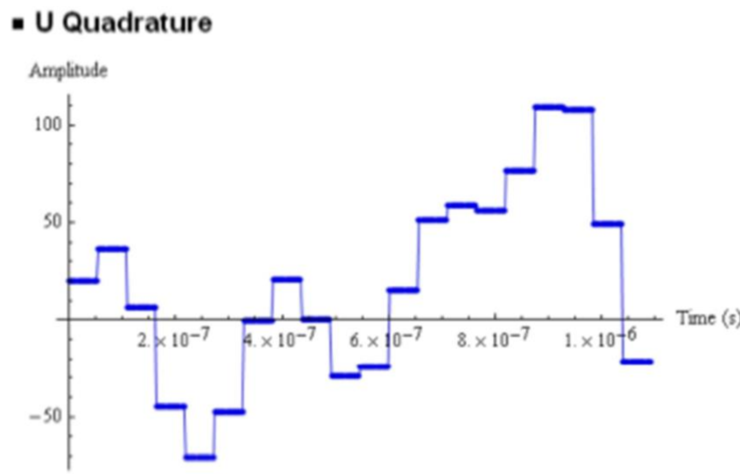
```
SequencePlot[g, FirstSampleIndex → 1, SequenceSamplingFrequency → Rs, Joined → True,
 AxesLabel → {"Time (s)", "Amplitude"}]
```

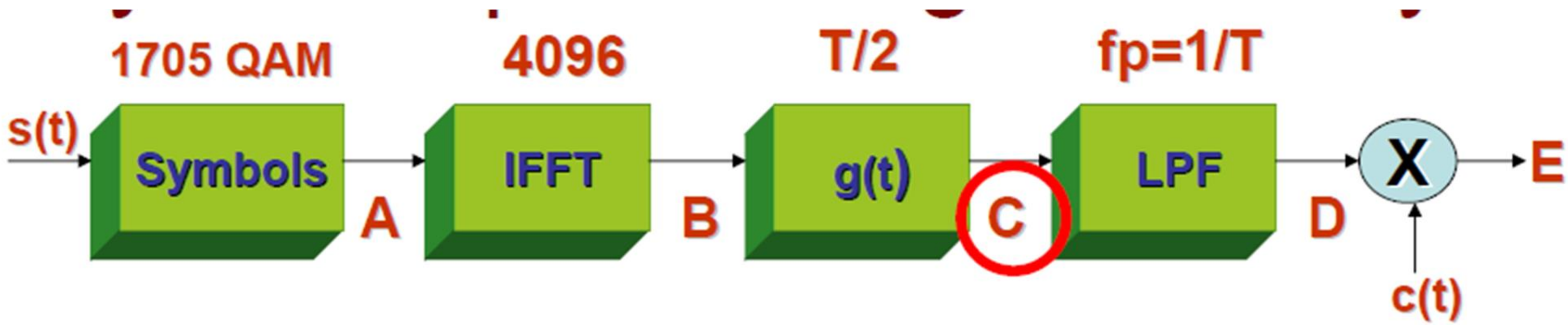


- To get continuous-time signal, a pulse shape g(t) is generated at **C**

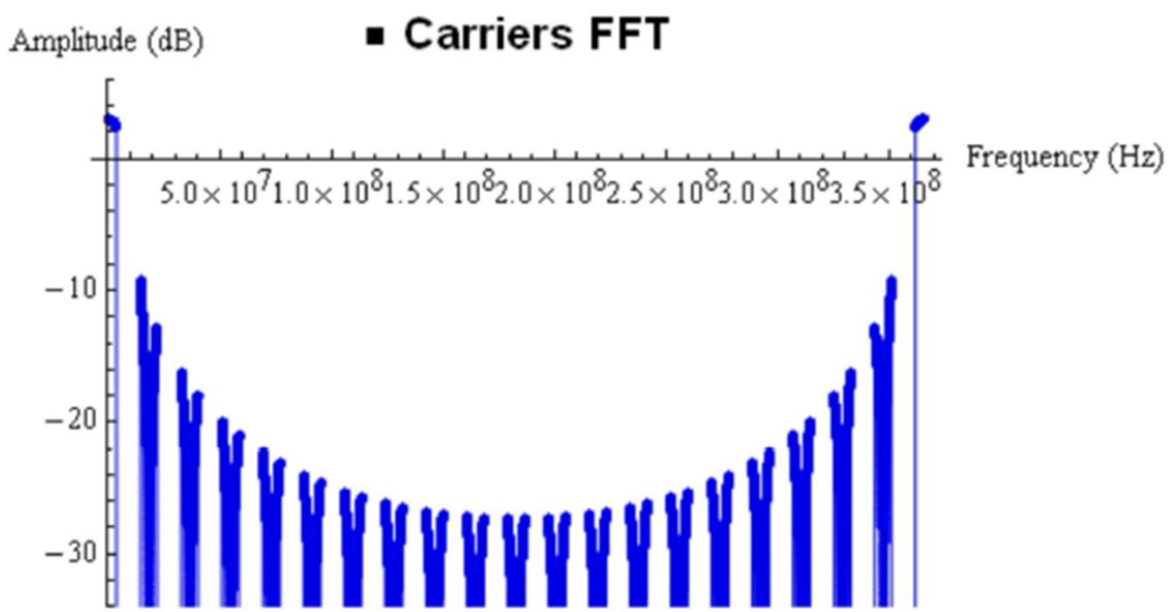

1705 QAM
4096
T/2
fp=1/T
s(t)
Symbols
IFFT
g(t)
LPF
X
E
A
B
C
D
c(t)


U Inphase
Amplitude
40
20
−20
−40
Time (s)
2. × 10−7
4. × 10−7
6. × 10−7
8. × 10−7
1. × 10−6

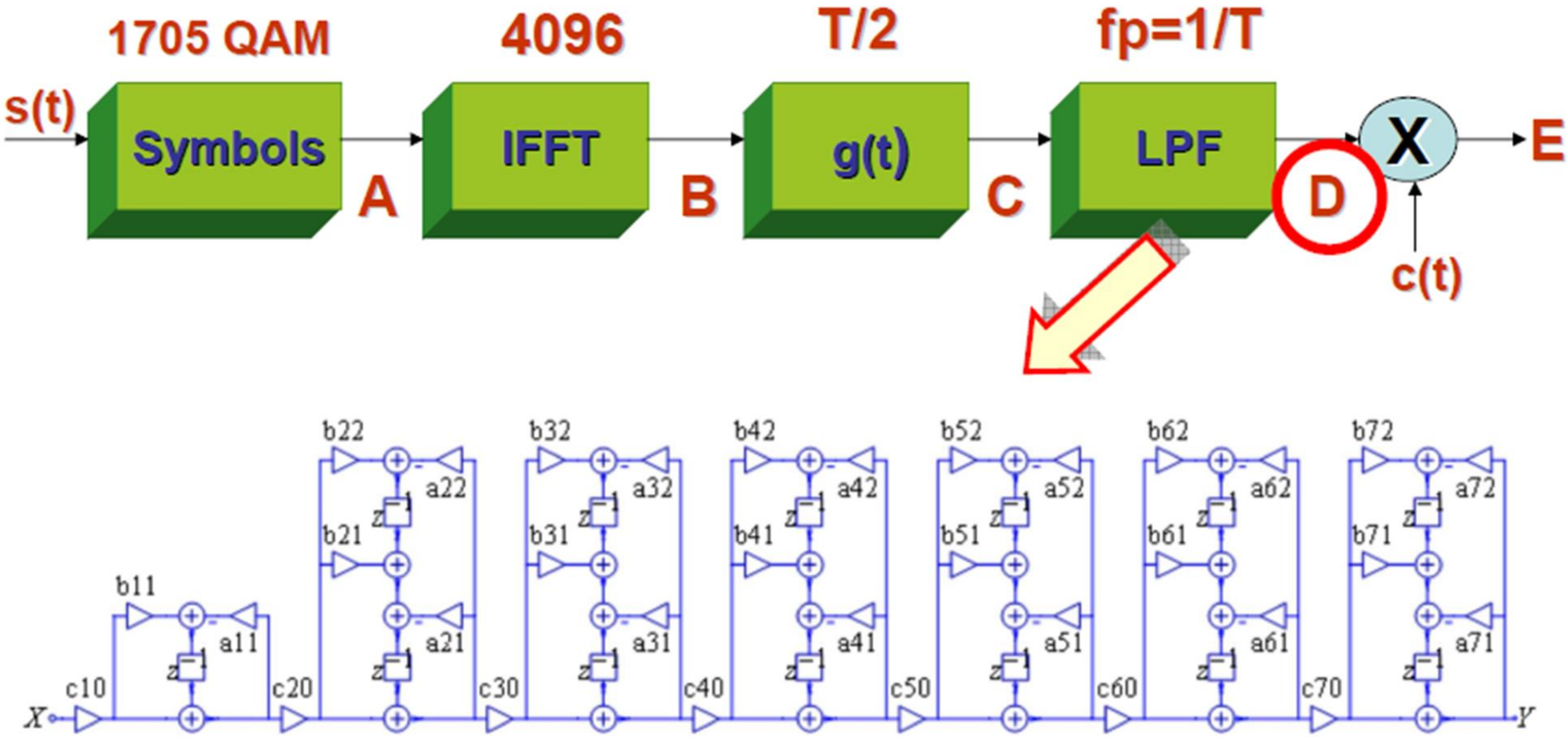

U Quadrature
Amplitude
100
50
−50
Time (s)
2. × 10−7
4. × 10−7
6. × 10−7
8. × 10−7
1. × 10−6



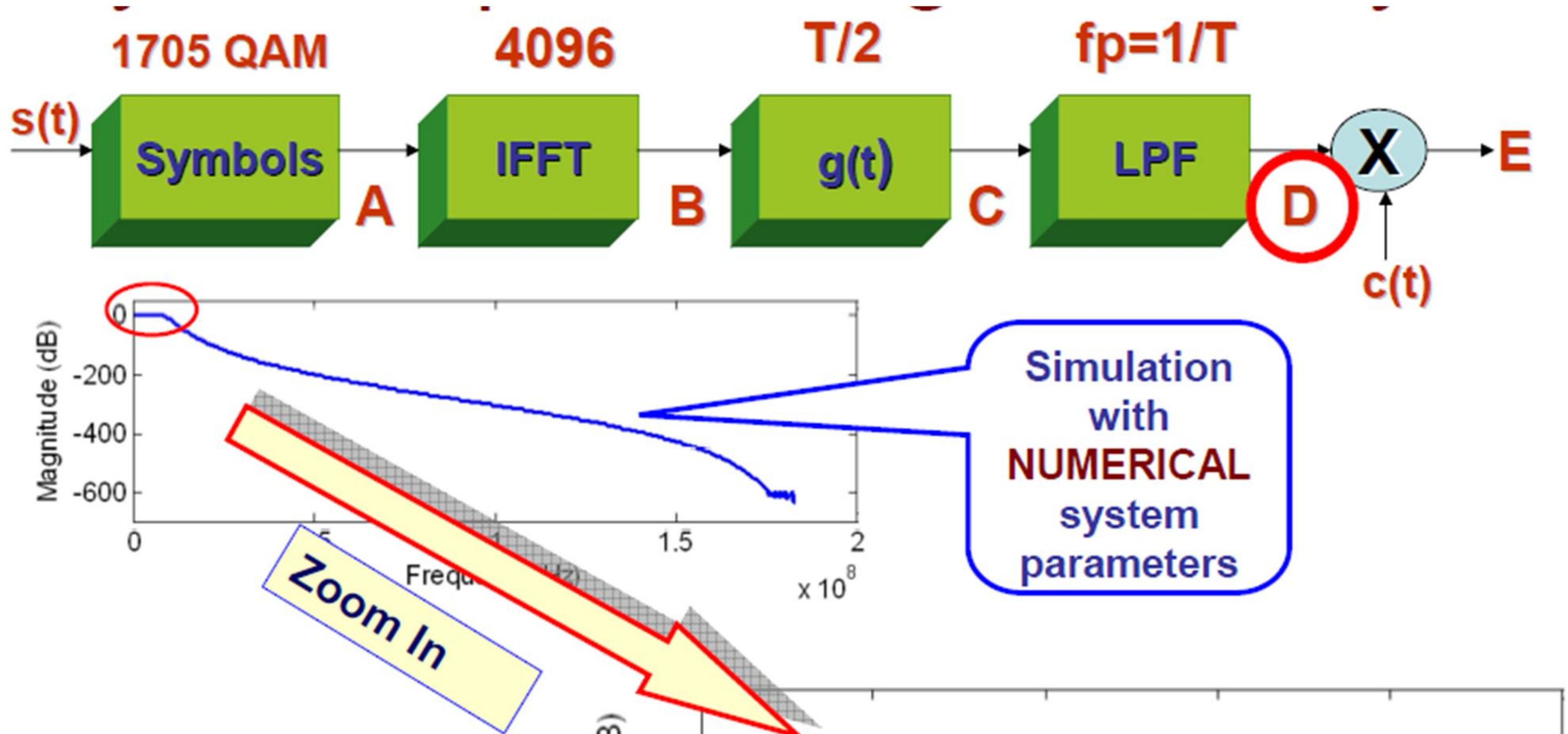
Frequency response of signal U at (C)

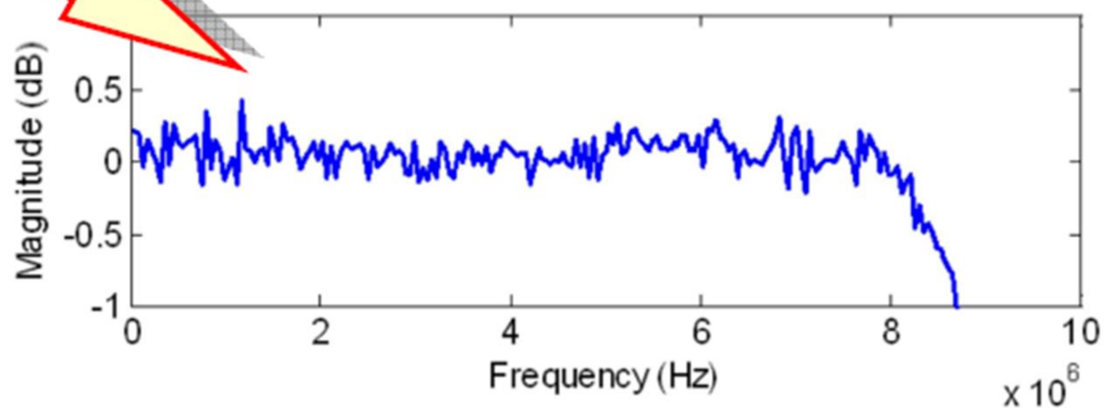


15

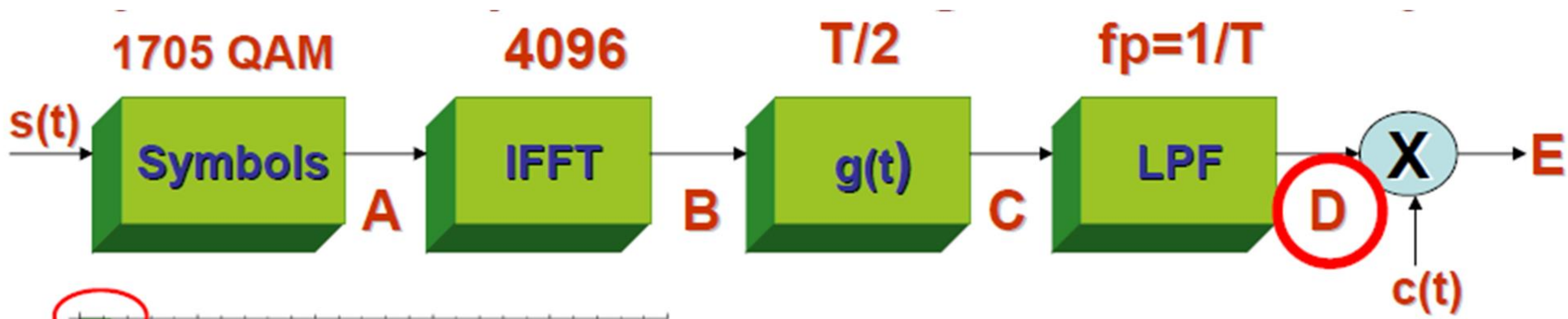


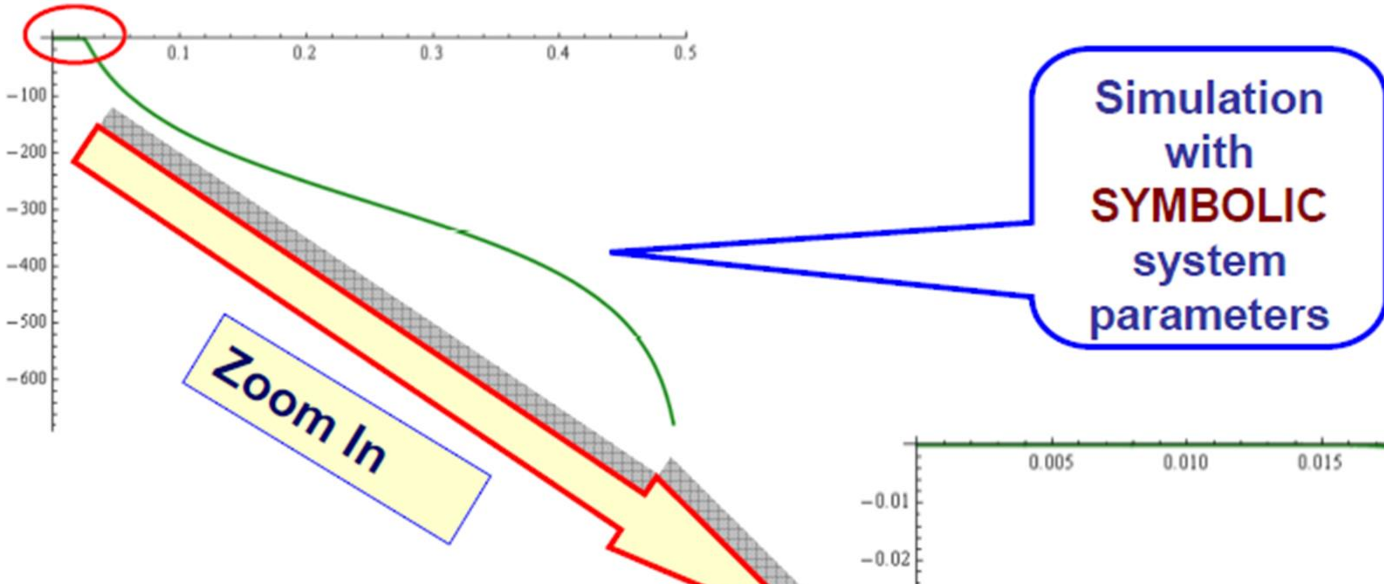
LPF is 13th-order Butterworth filter symbolic generated

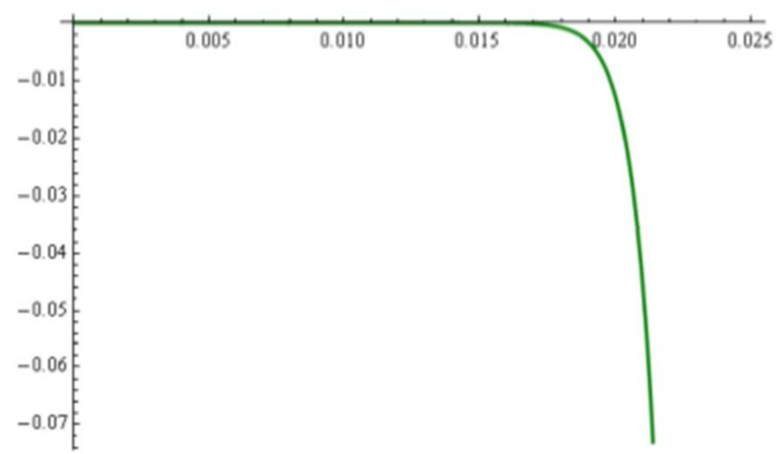




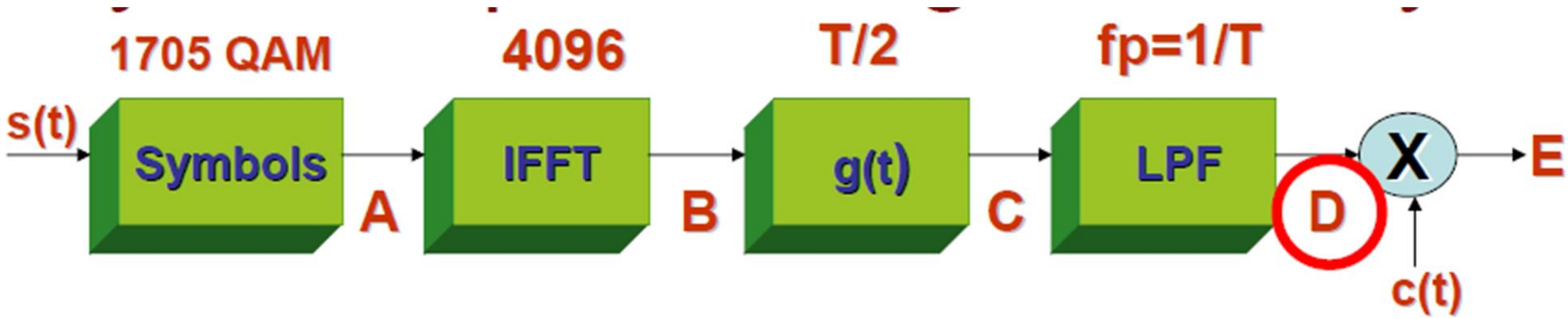
LPF is 13^{th}-order Butterworth filter

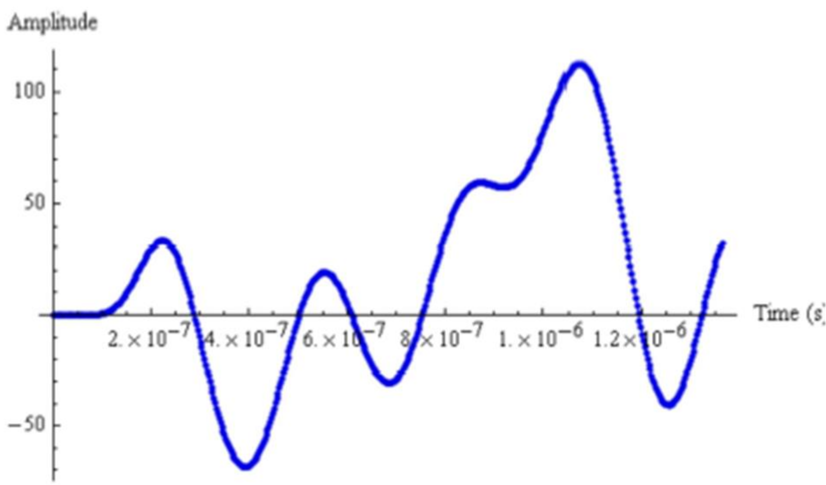


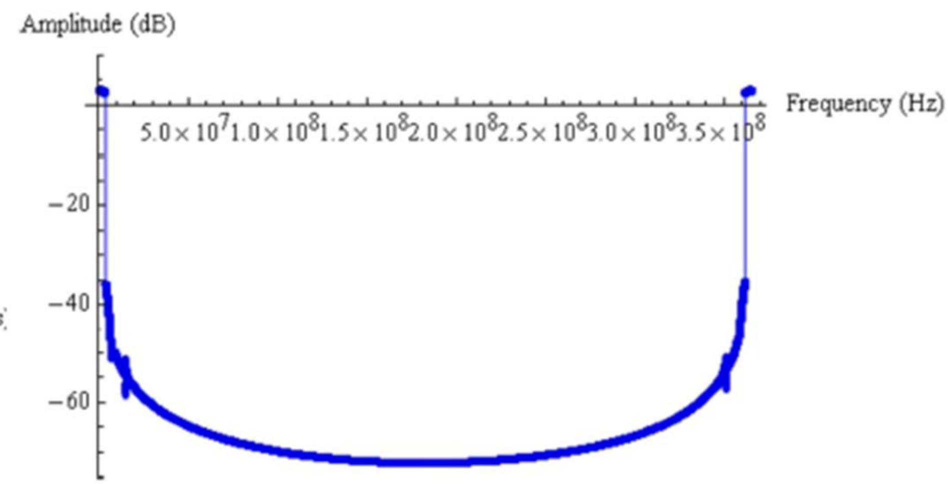




LPF is 13th-order Butterworth filter generated symbolically



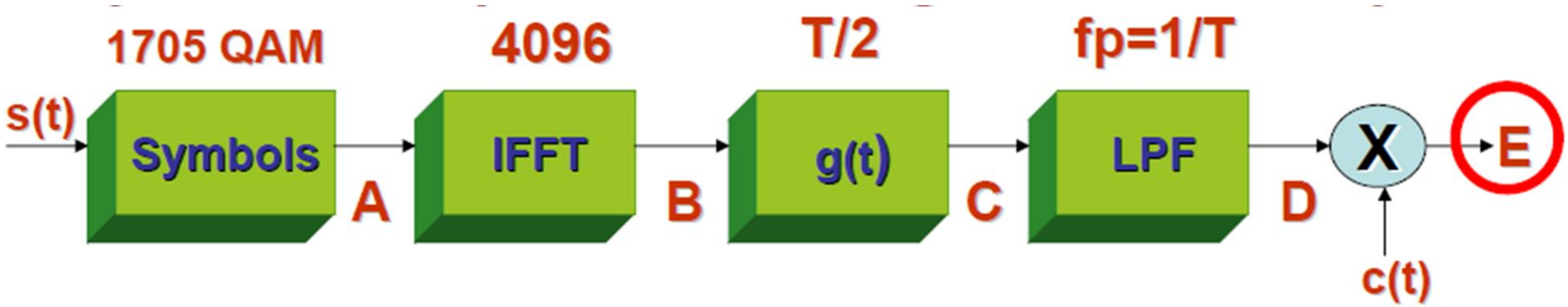


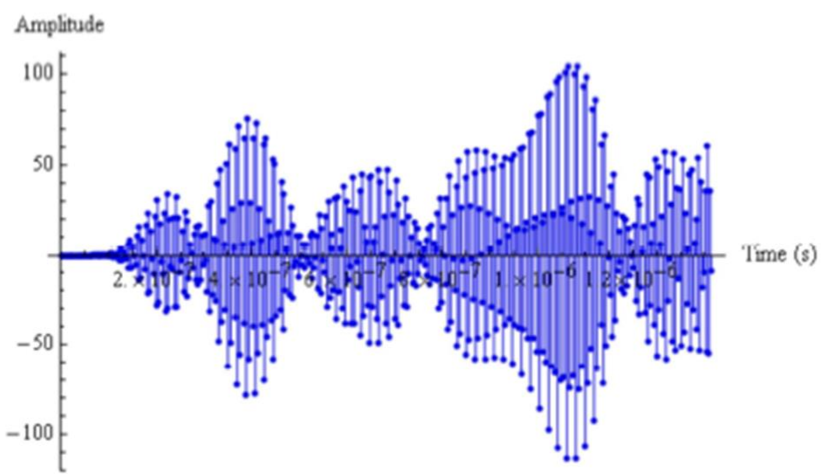


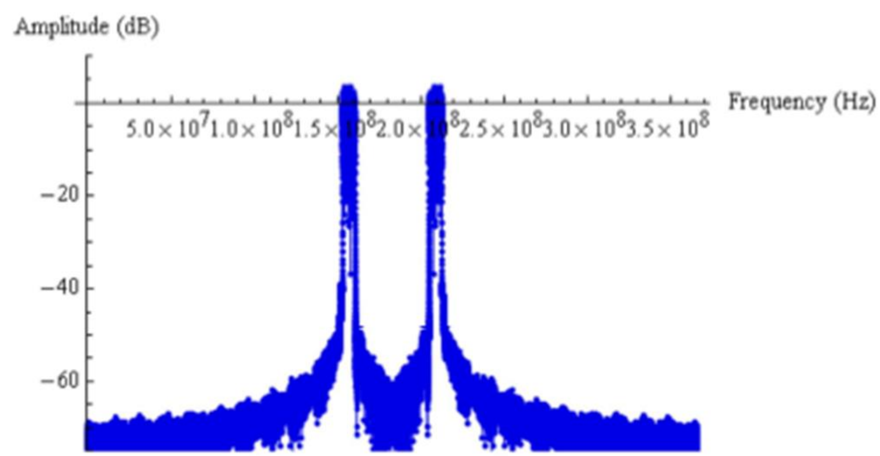
Inphase filtered signal at **D**

Frequence response at **D**

19







Transmited signal at **E**

Frequence response at **E**

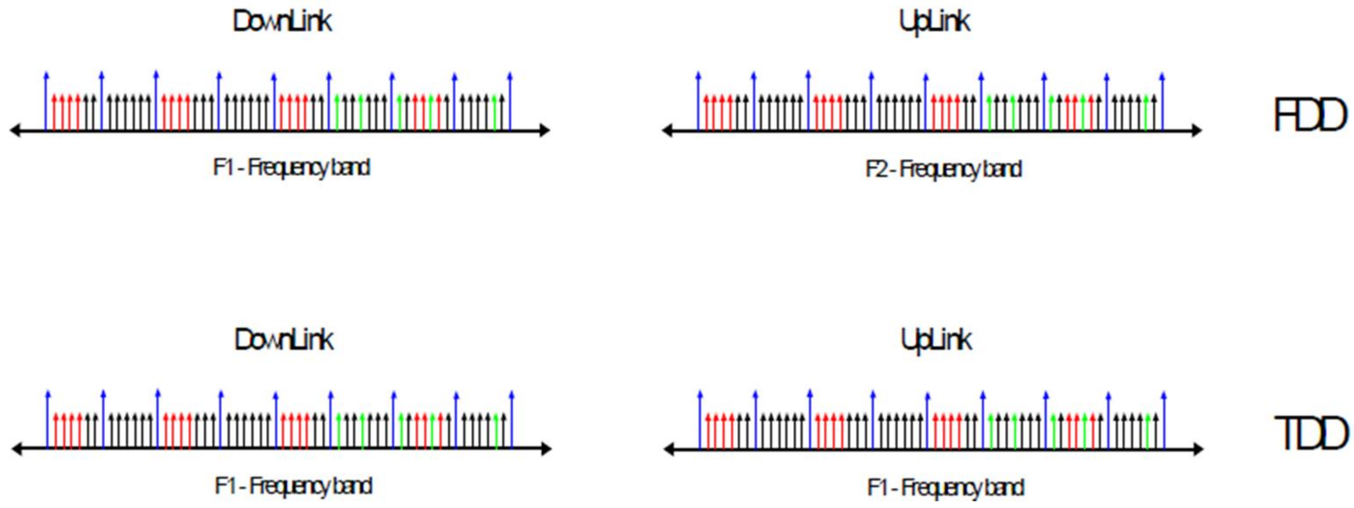
20

Duplexing - Principles

FDD (Frequency Division Duplexing) Uses One Frequency for the DownLink, and a Second Frequency for the UpLink.

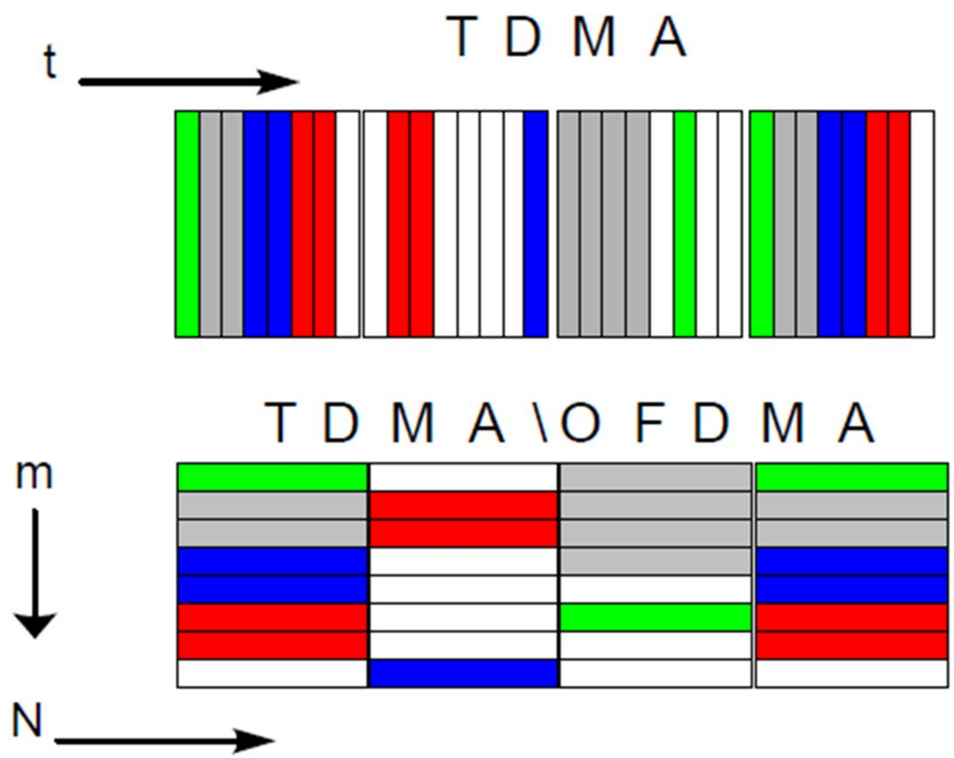
TDD (time Division Duplexing) Uses the same frequency for the Downlink and the Uplink.

In any configuration the access method is OFDMA/TDMA .

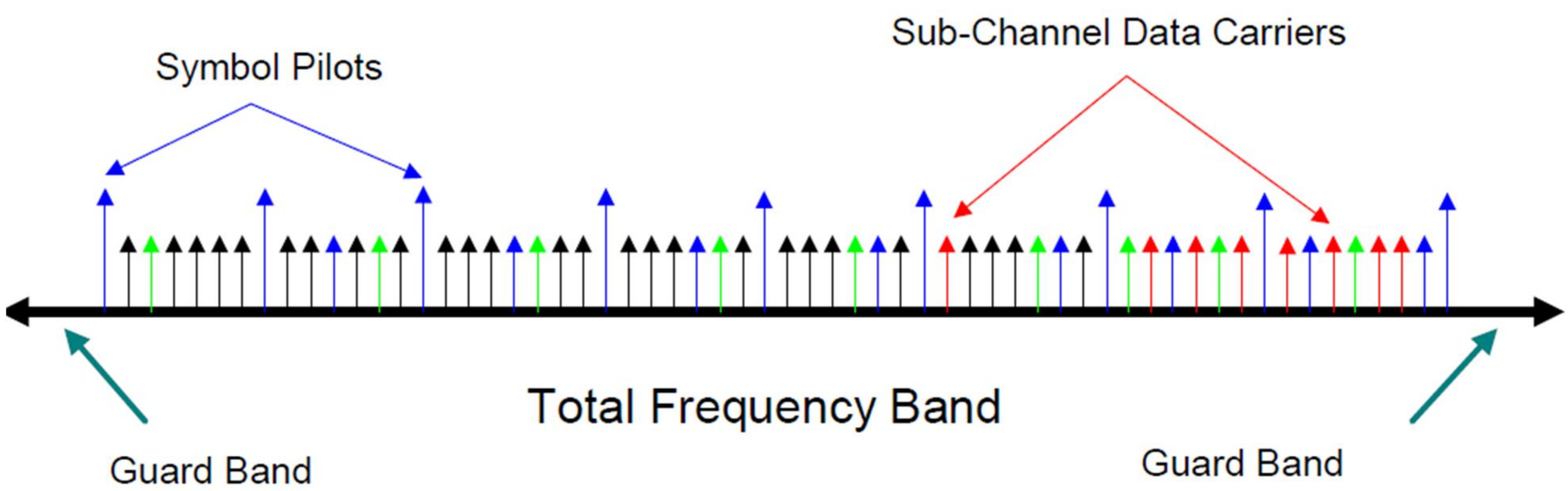


OFDMA-TDMA Principles

Using OFDMA/TDMA, Sub Channels are allocated in the Frequency Domain, and OFDM Symbols allocated in the Time Domain.



DownLink OFDMA Symbol



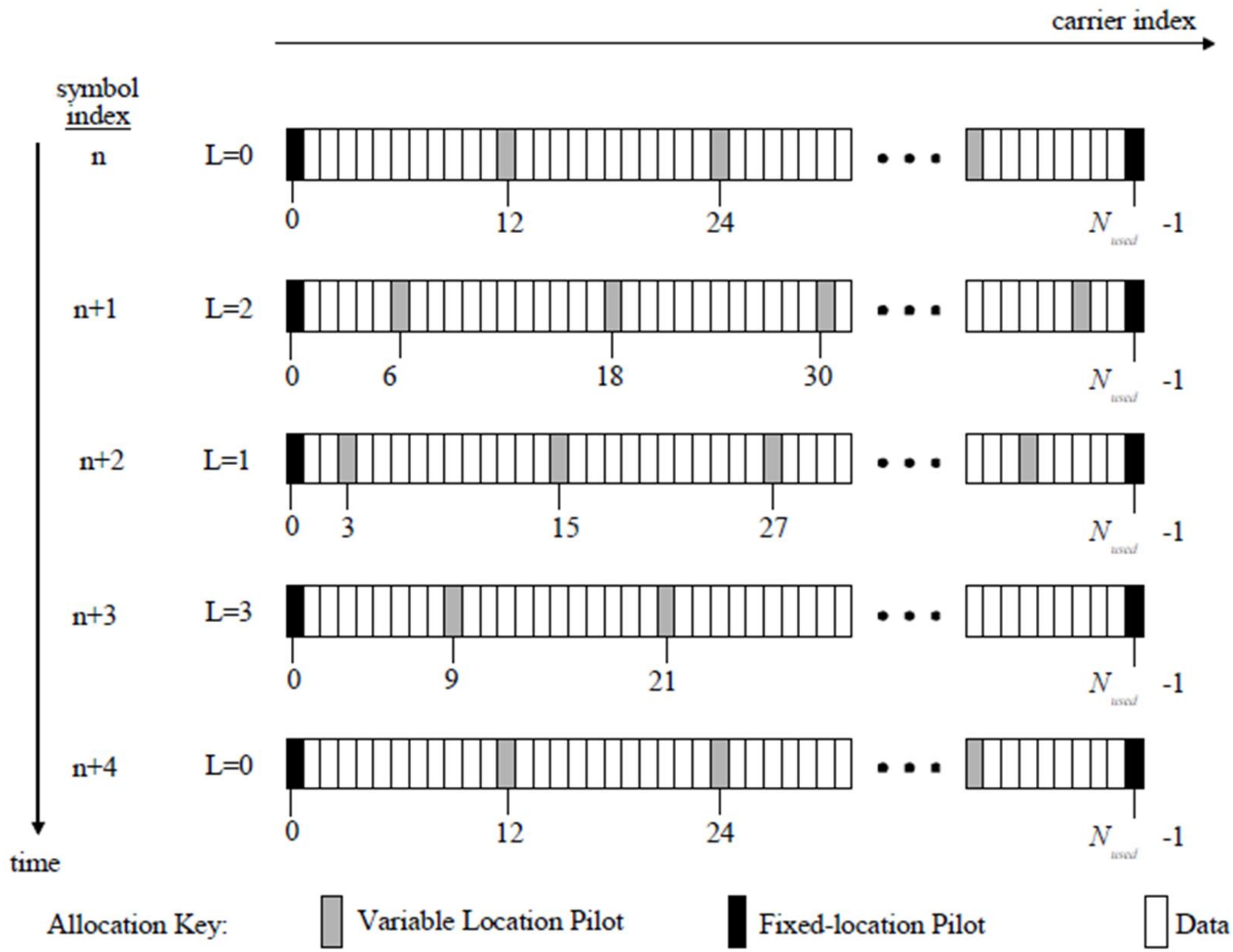
DownLink Specification

- Burst Structure is defined from one Sub-channel in the Frequency domain and n OFDMA time symbols in the time domain, each burst consists of N data modulated carriers.
- Adaptive Modulation and Coding per Sub-Channel in the Down-Link
- Forward APC controlling (+6dB) – (-6dB) digital gain on the transmitted Sub-Channel
- Supporting optional Space Time Coding employing Alamouti STC.
- Supporting optional Adaptive Array.

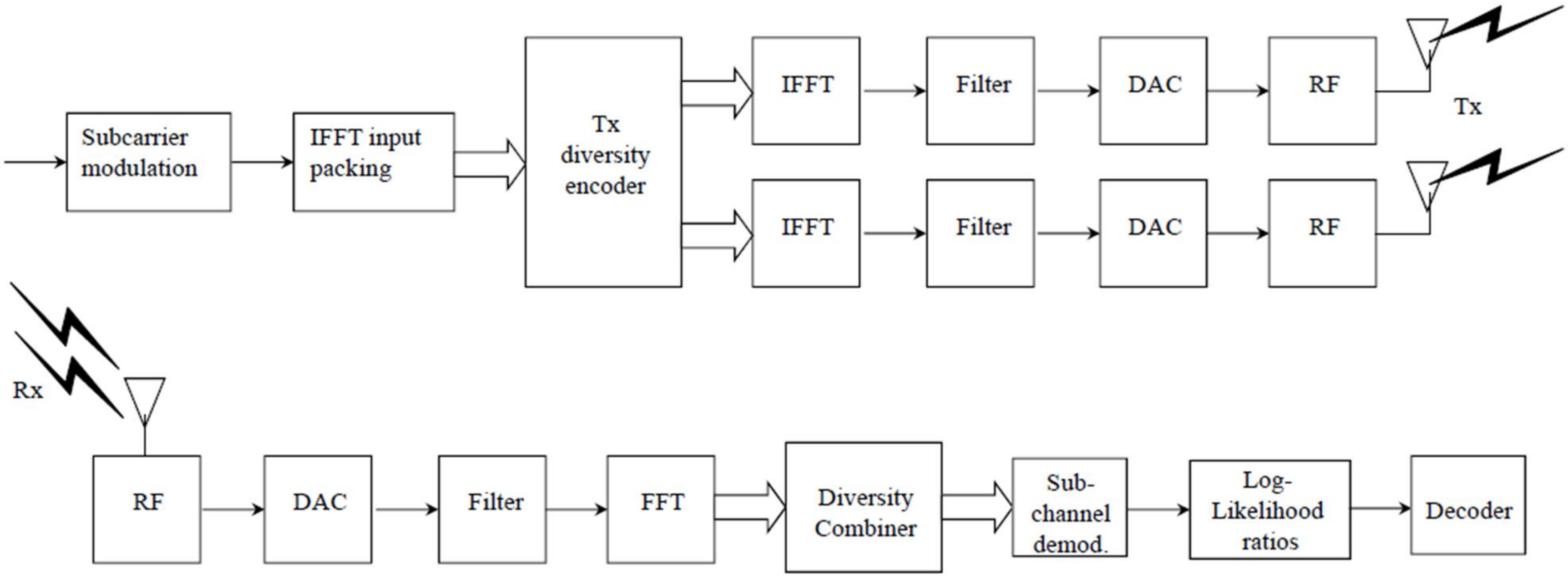
Example- DownLink Specification

- FFT size : 2048
- Guard Intervals : ¼, 1/8, 1/16, 1/32
- Coding Mandatory: concatenated RS GF(256) and Convolutional coding (k=7,G1=171,G2=133, keeping overall coding rate to = ½, ¾
- Coding Optional: Convolutional Turbo Code (CTC), Turbo Product Code (TPC) with coding rates close to = ½, ¾
- QPSK, 16QAM, 64QAM modulation
- Modulo 4, Pilot based Symbol Structure.
- 32 Sub-Channels of 48 data carriers each

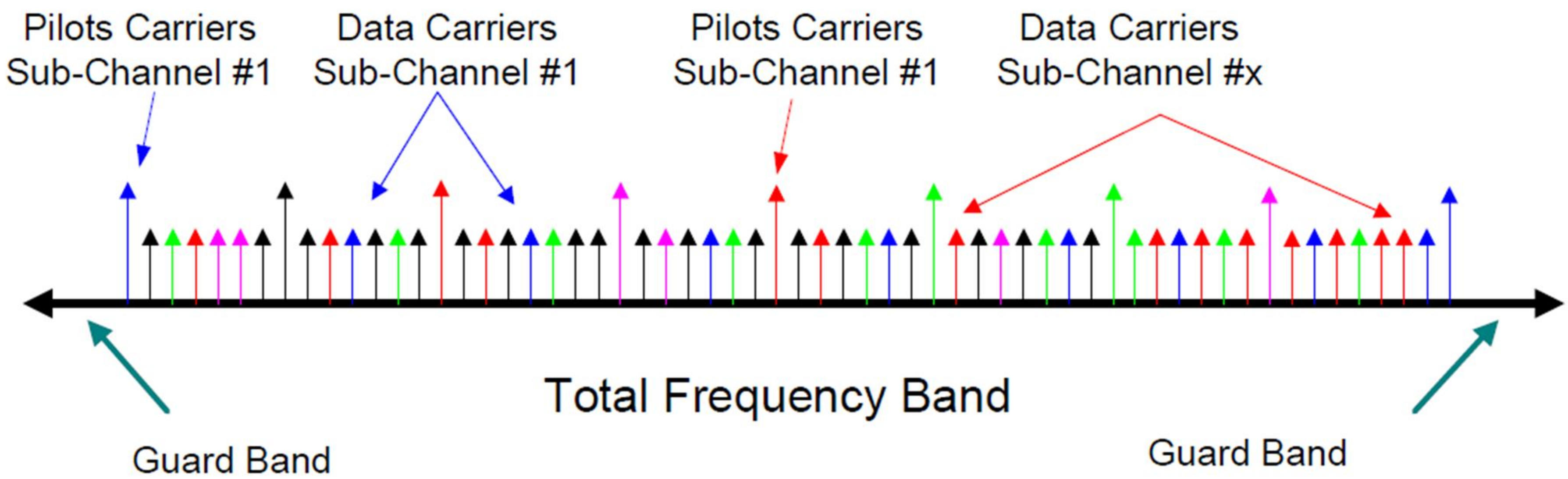
Downlink Pilot and Data Carriers Allocation Scheme



Space Time Coding



UpLink OFDMA Symbol



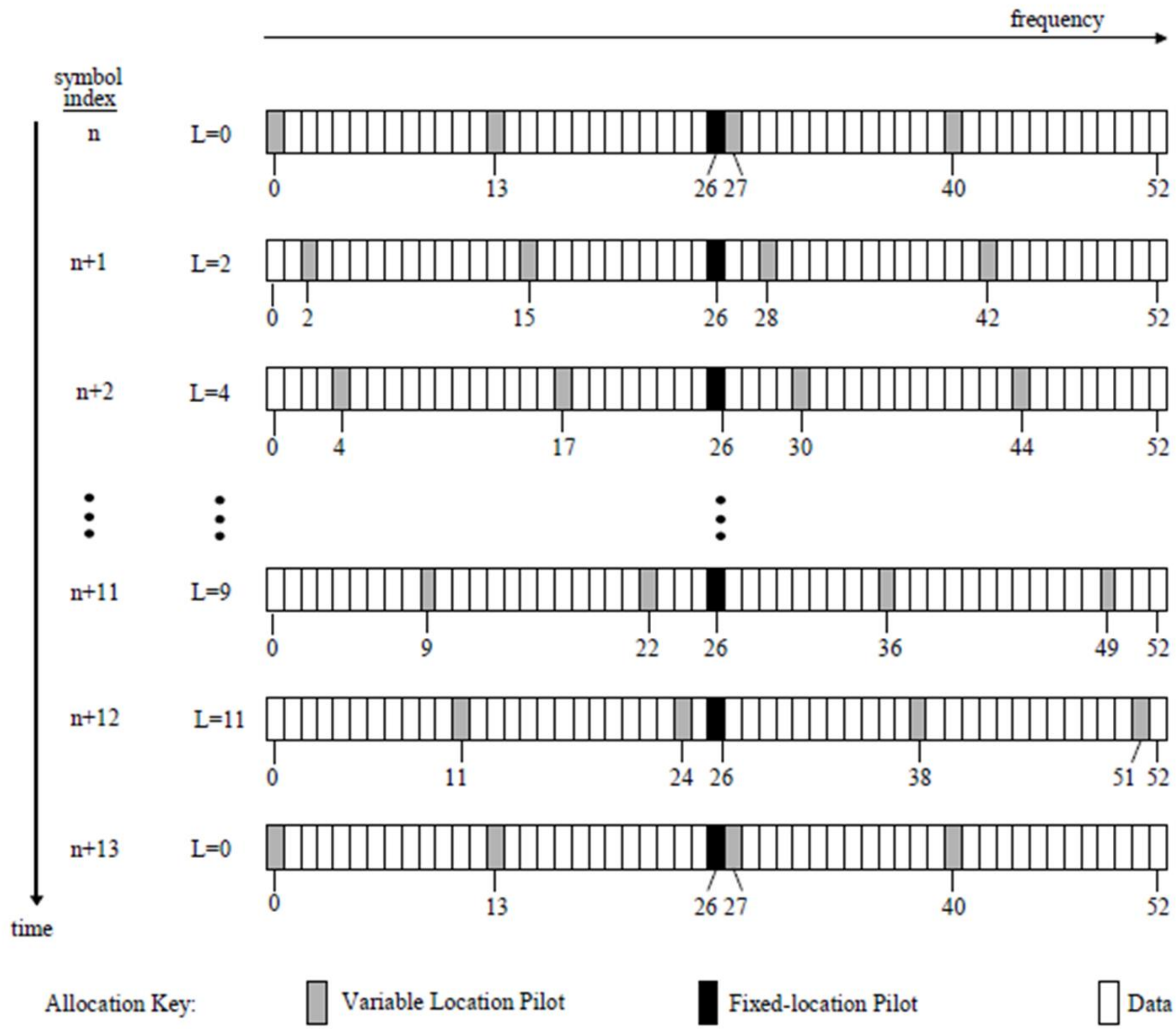
Example of UpLink Specification

- Burst Structure is defined from one Sub-channel in the Frequency domain and 3 OFDMA time symbols in the time domain, each burst consists of 144 data modulated carriers.
- Adaptive Modulation and Coding per User in the UpLink
- User Can be allocated 1 up to 32 Sub-Channels
- 2 Sub-Channels are used as the Ranging Sub-Channels for User Ranging and fast Band-Width Request.

Example of UpLink Specification

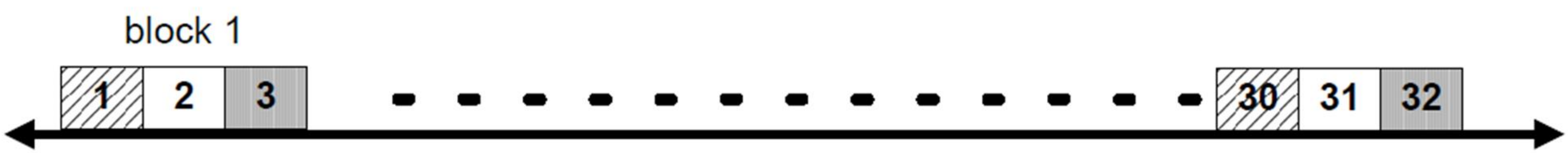
- FFT size : 2048
- Guard Intervals : ¼, 1/8, 1/16, 1/32
- Coding Mandatory: concatenated RS GF(256) and Convolutional coding (k=7,G1=171,G2=133, keeping overall coding rate to = ½, ¾
- Coding Optional: Convolutional Turbo Code (CTC), Turbo Product Code (TPC) with coding rates close to = ½, ¾
- QPSK, 16QAM, 64QAM modulation
- Modulo 13, Pilot based Sub-Channel Structure.
- 32 Sub-Channels of 53 carriers each, 5 carriers used as pilots, 48 carriers used for data

Example for UpLink Sub-Channel Pilot and Data Carriers Allocation Scheme

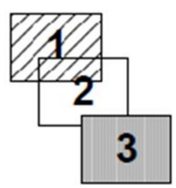


Using Special Permutations for carrier allocation

- All usable carriers are divided into 32 carrier groups named basic group, each main group contains 53 basic groups.



each group contains
53 carriers

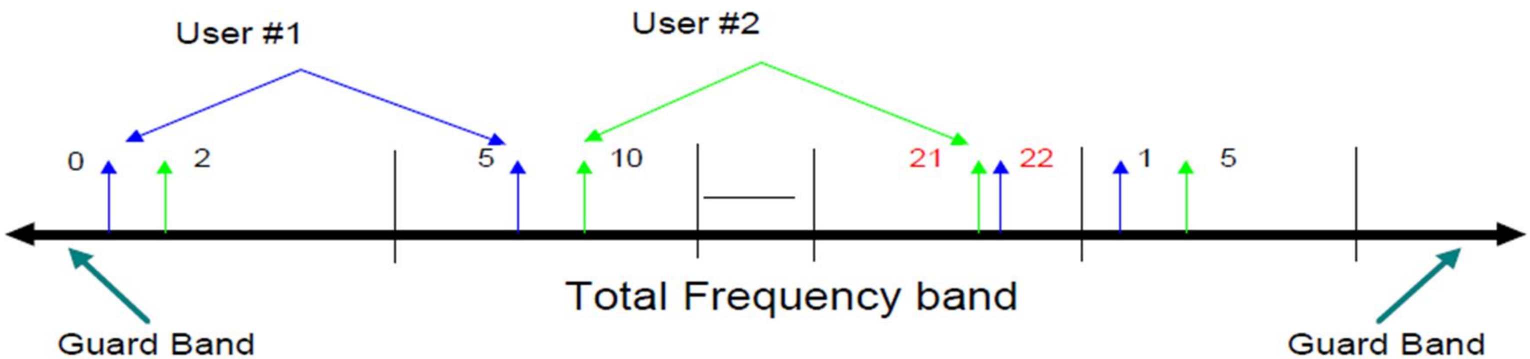


Using Special Permutations for carrier allocation

- Carriers are allocated by a basic series and it's cyclic permutations for example:
- Basic Series:

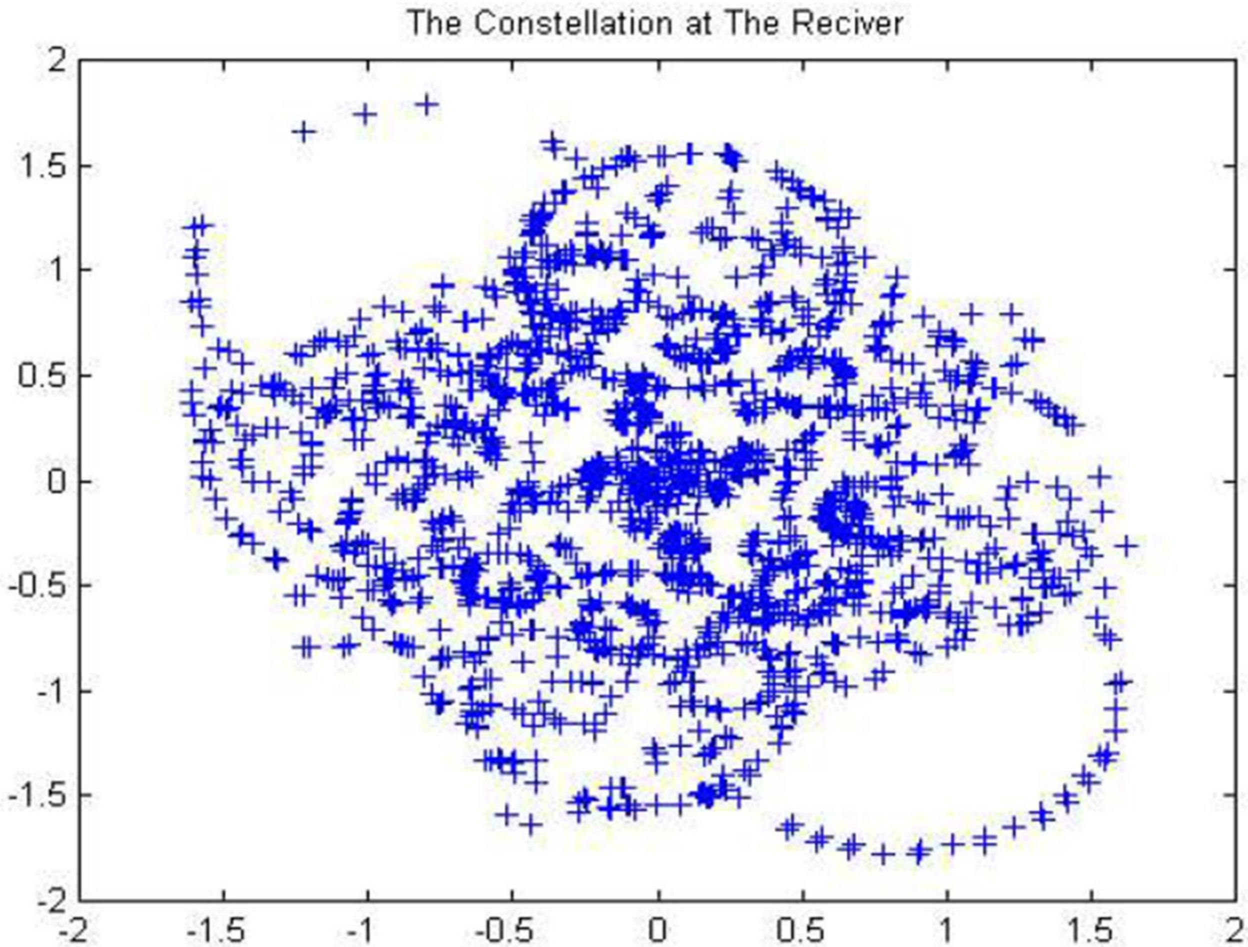
  0,5,2,10,4,20,8,17,16,11,9,22,18,21,13,19,3,15,6,7,12,14,1
- After two cyclic permutations we get:

  2,10,4,20,8,17,16,11,9,22,18,21,13,19,3,15,6,7,12,14,1,0,5

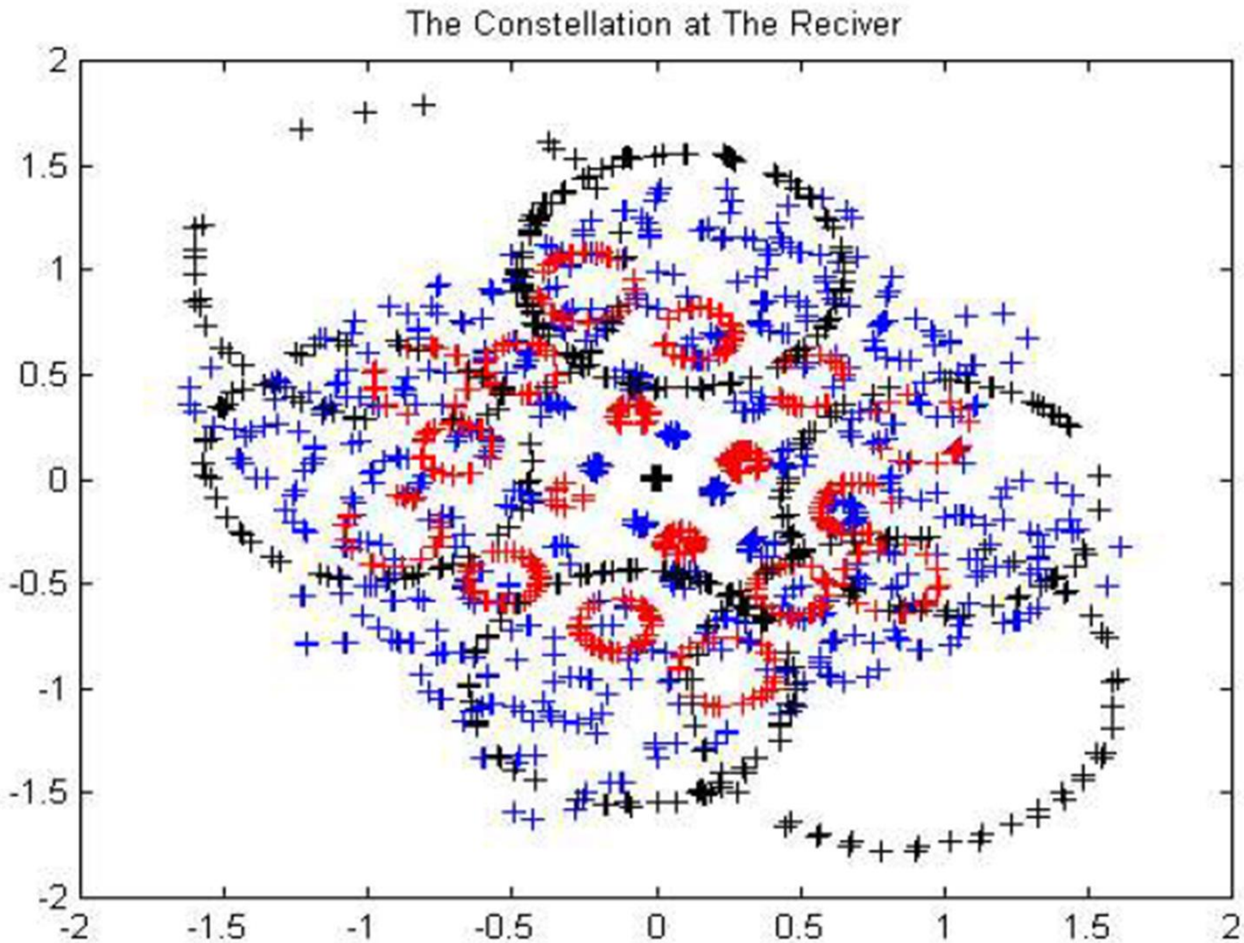


User 1 = 0,5,2,10,4,20,8,17,16,11,9, 22,18,21,13,19,3,15,6,7,12,14,1
User 2 = 2,10,4,20,8,17,16,11,9,22,18, 21,13,19,3,15,6,7,12,14,1,0,5

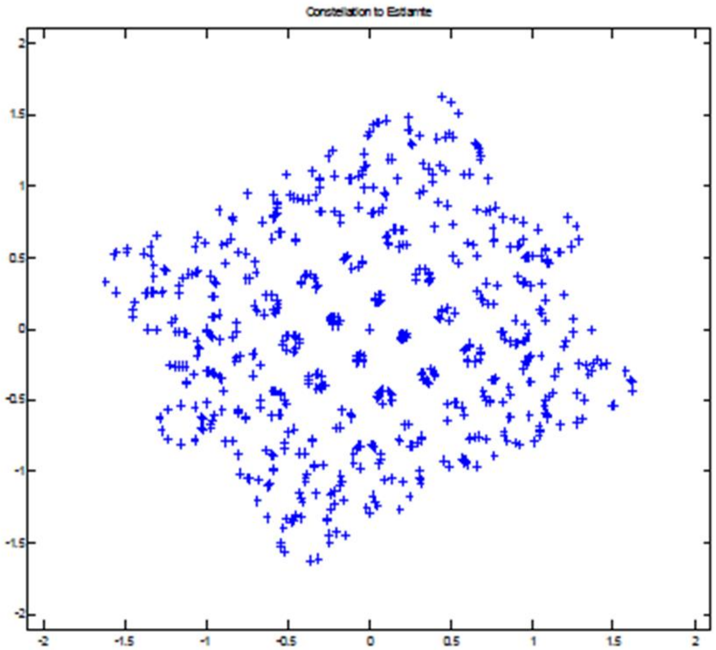
- Constellation at the Base Station

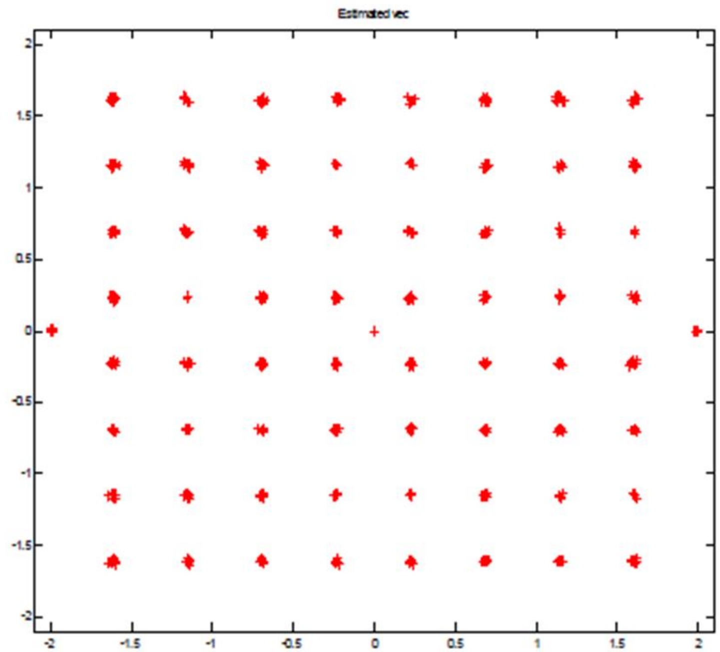


- Users Separation

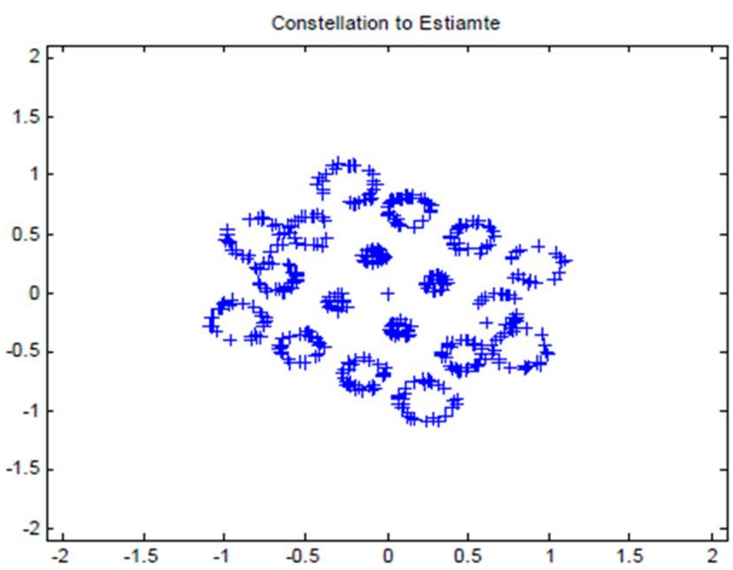


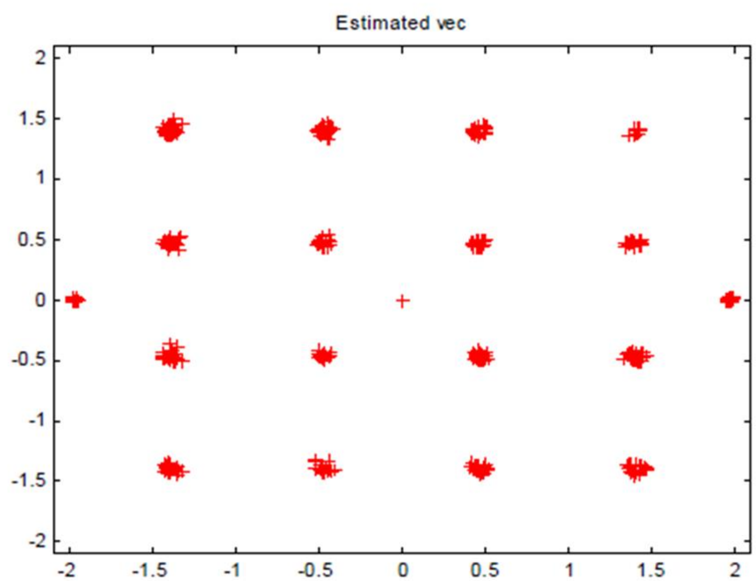
- User Estimation



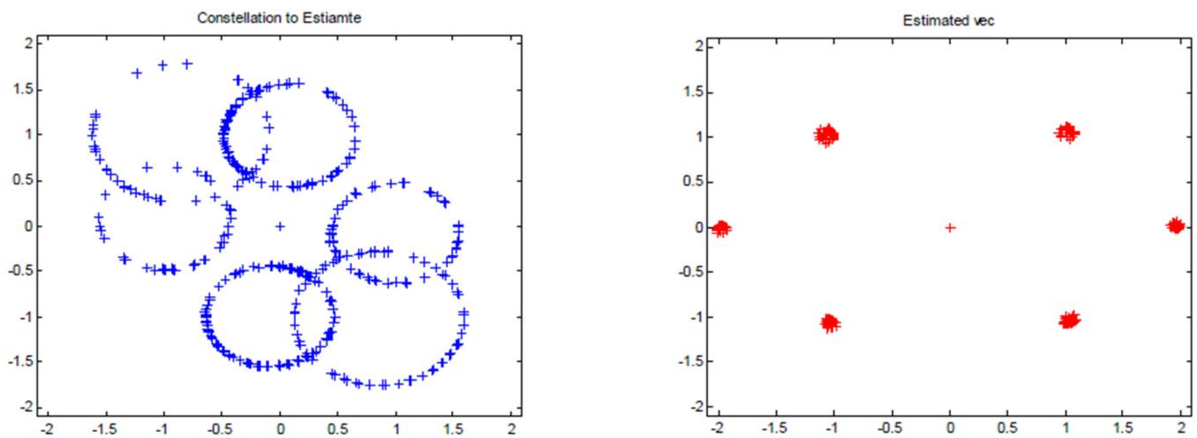


- User Estimation

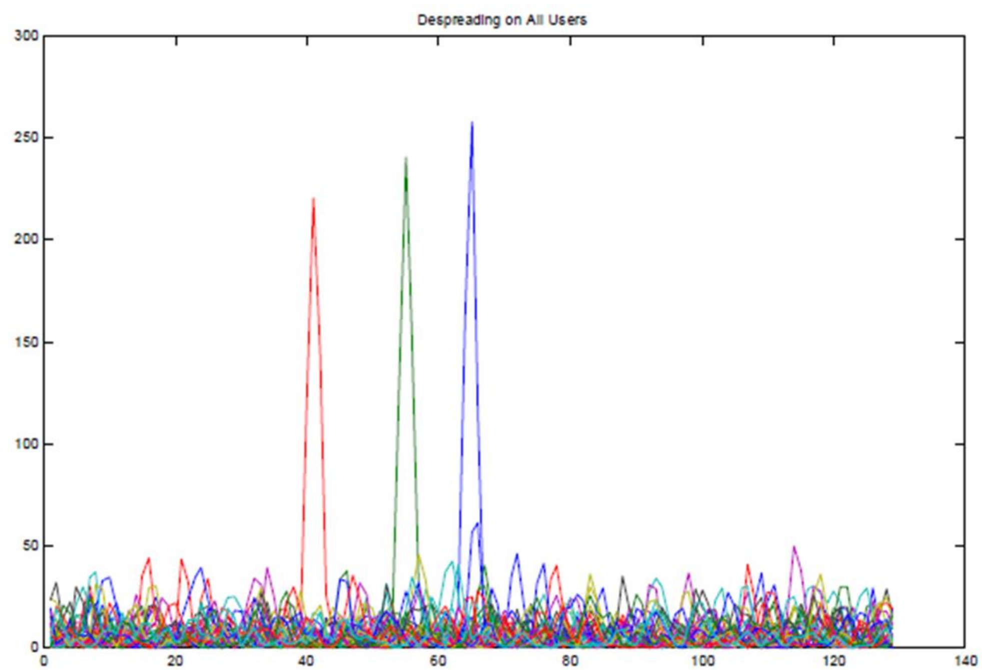




- User Estimation

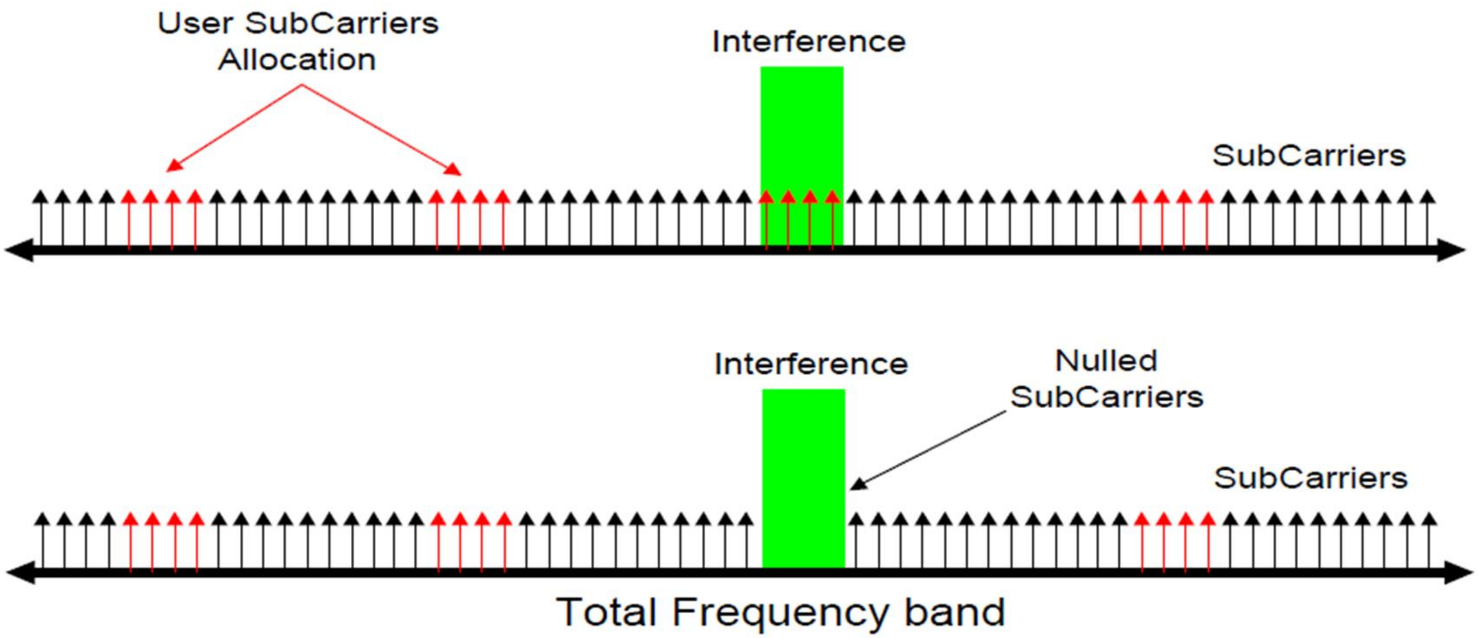


- Finding New Subscriber-Units Requesting Services, Using the Ranging Pilots (CDMA/OFDM Techniques)

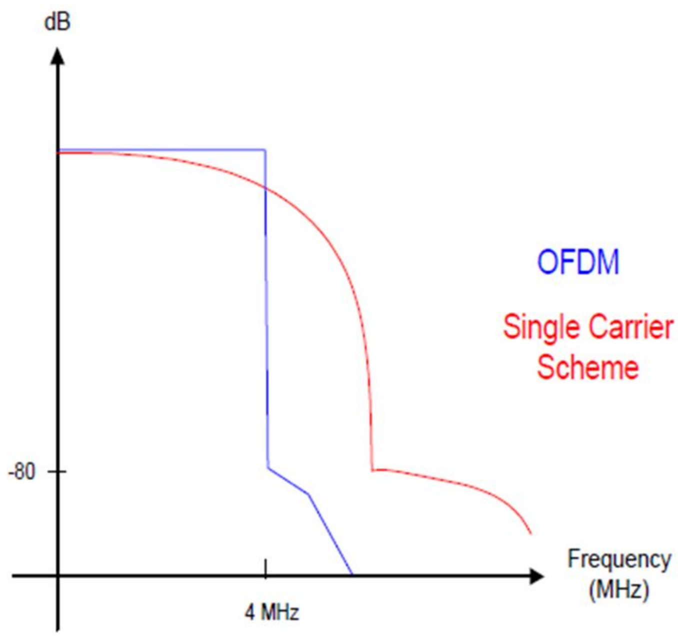


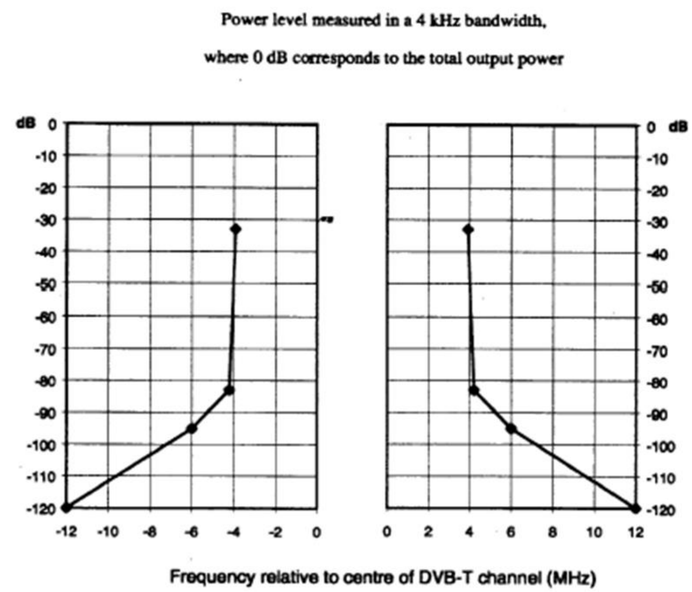
Interference Rejection/Avoidance

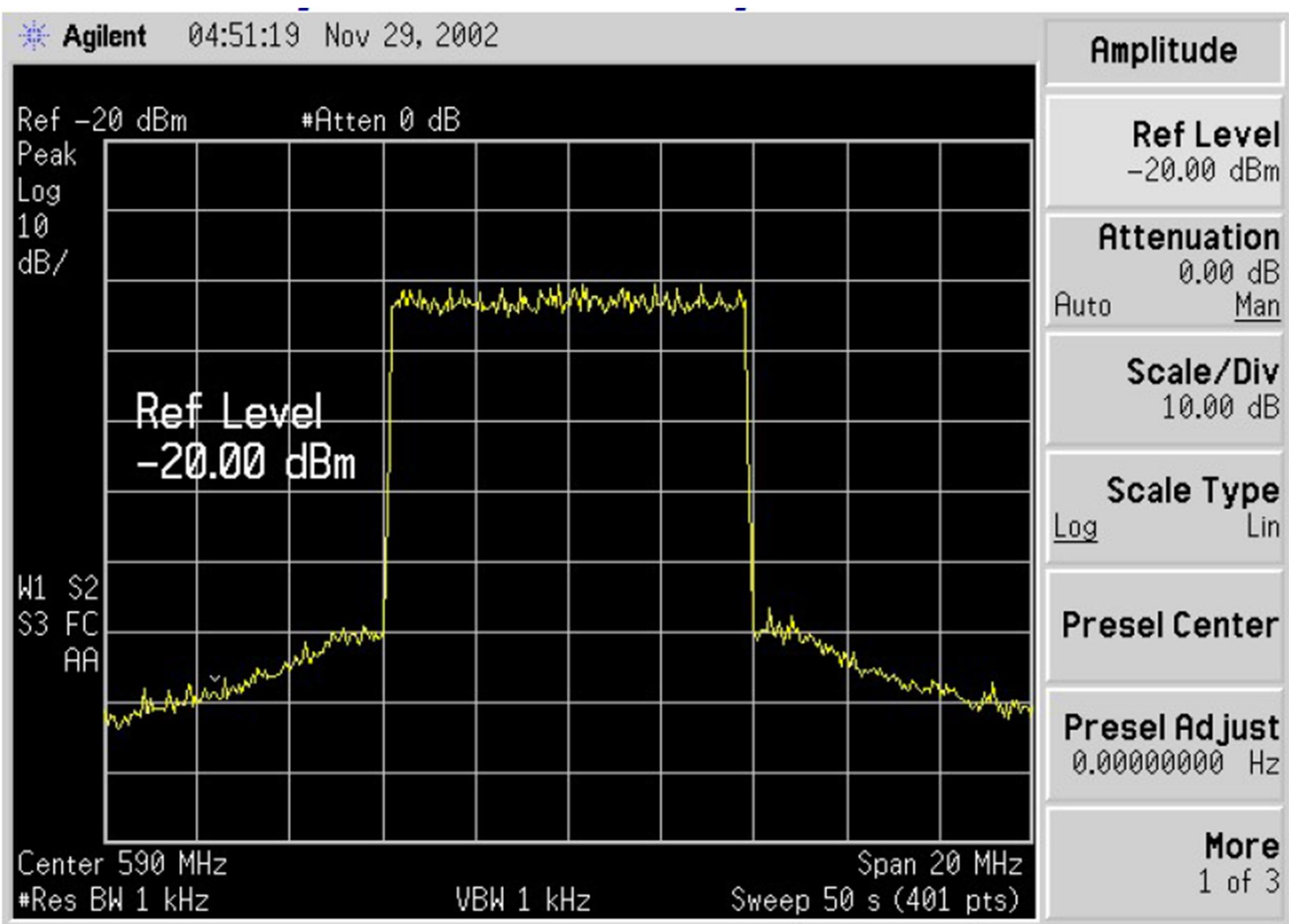
- Narrowband Interference Rejection
  - Easy to Avoid/Reject Narrowband Dominant Interference .
  - Less Interfered Part of the Carrier Can Still Be Used .

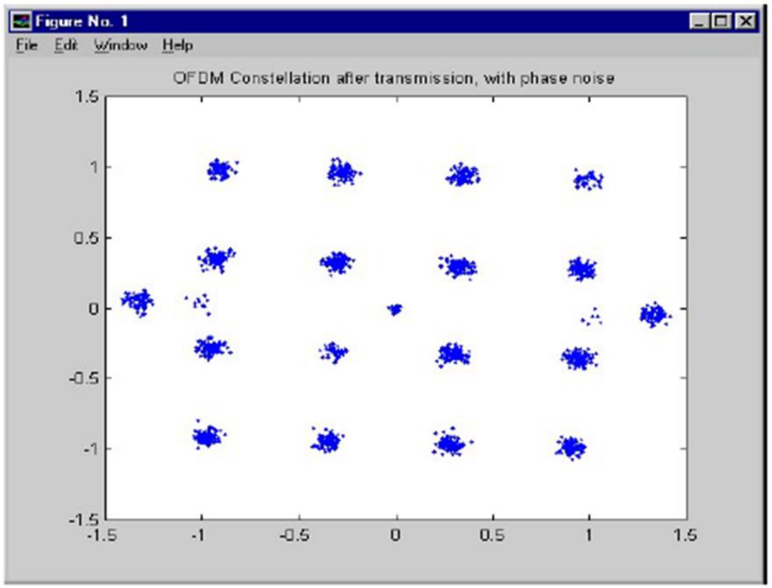


- Rectangular Spectrum Shape (Brick Wall)
- Small Frequency Guard band

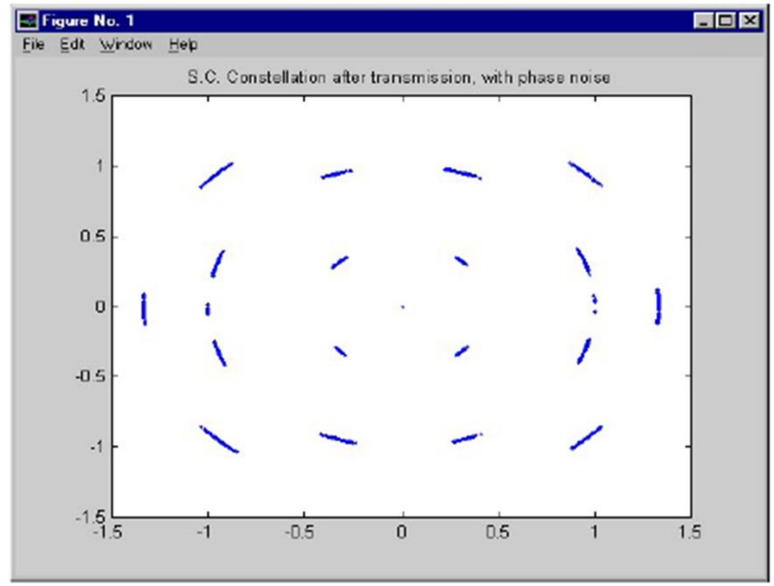




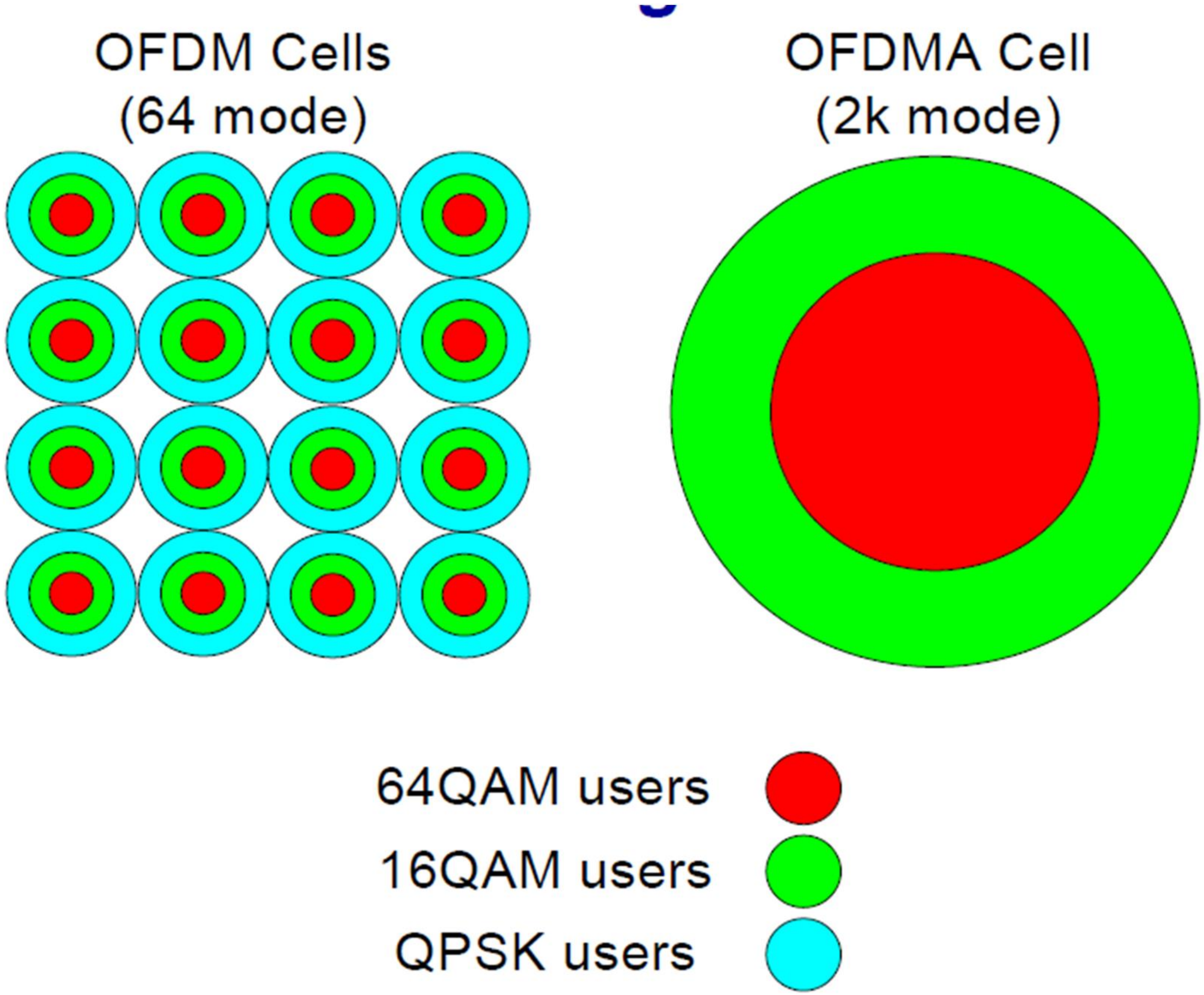

Agilent 04:51:19 Nov 29, 2002
Ref -20 dBm
#Atten 0 dB
Peak
Log
10
dB/
Ref Level
-20.00 dBm
W1 S2
S3 FC
AA
Center 590 MHz
Span 20 MHz
#Res BW 1 kHz
VBW 1 kHz
Sweep 50 s (401 pts)
Amplitude
Ref Level
-20.00 dBm
Attenuation
0.00 dB
Auto
Man
Scale/Div
10.00 dB
Scale Type
Log
Lin
Presel Center
Presel Adjust
0.00000000 Hz
More
1 of 3

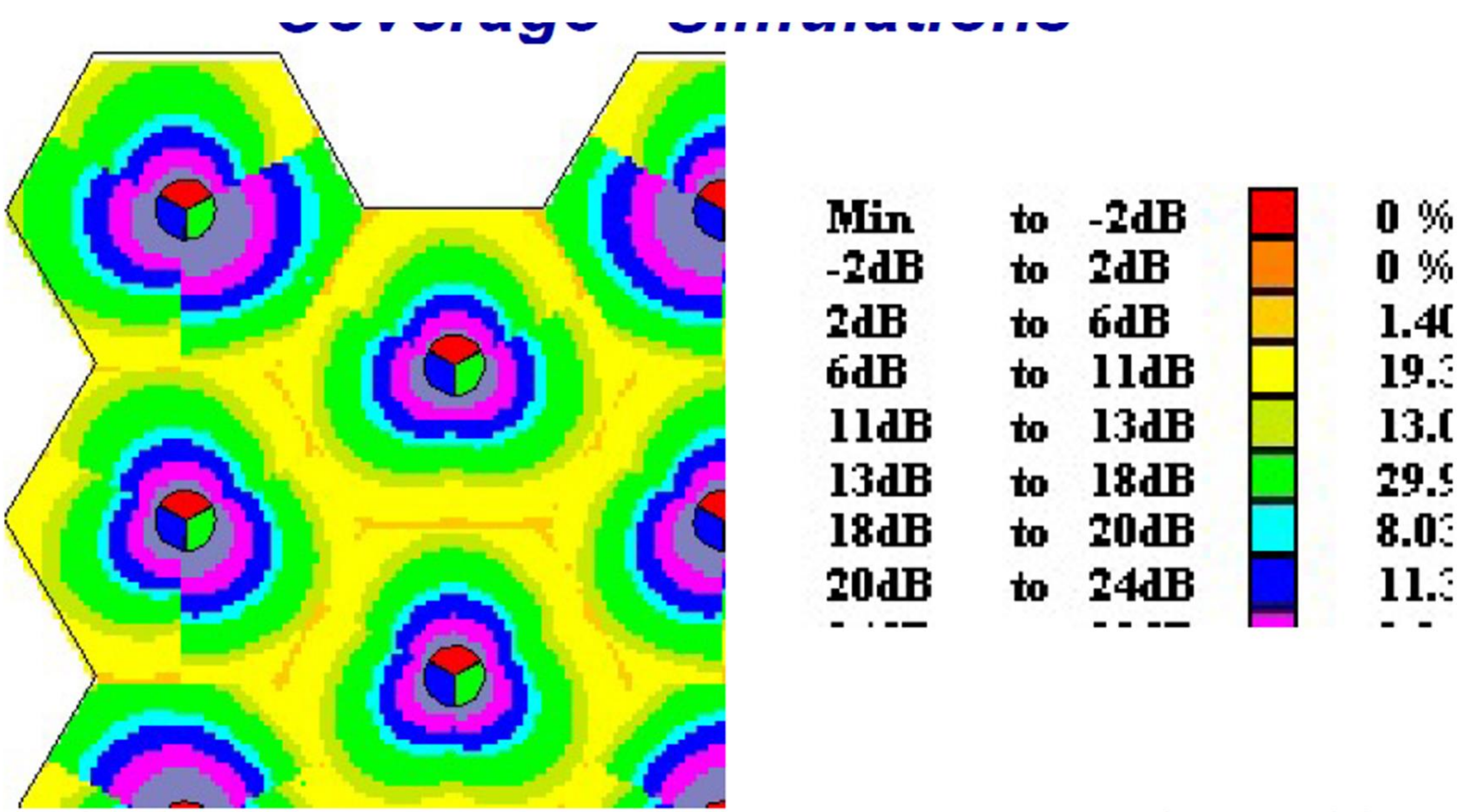


Phase Noise Effect on OFDM



Phase Noise Effect on S.C


OFDM Cells
(64 mode)
OFDMA Cell
(2k mode)
64QAM users
16QAM users
QPSK users



Multi Sector Coverage, 3 Sectors, 3 Frequencies, achieves 2.8Bits/s/Hz/Cell, 22.5Mbps/Sector

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