Key Technologies in the PHY of WiMAX

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Oct. 7, 2005

Outlines

- BPSK/QPSK/QAM
- OFDM/OFDMA
- Subchannelization
- AAS/Beamforming

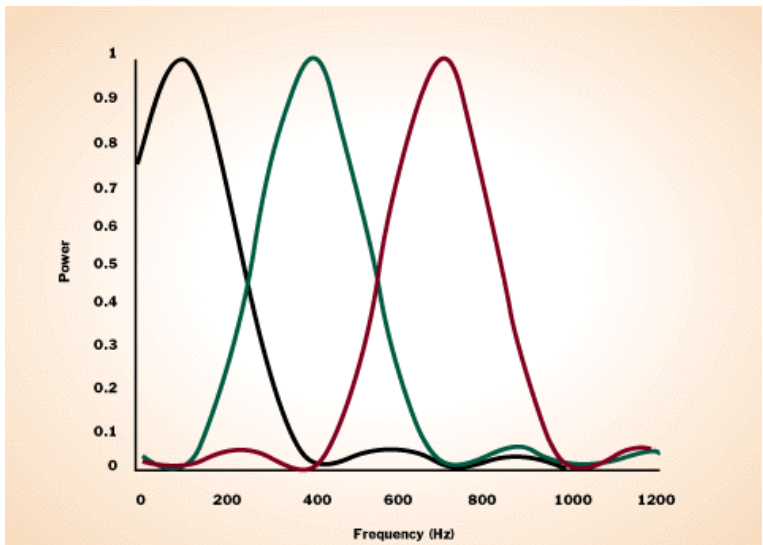
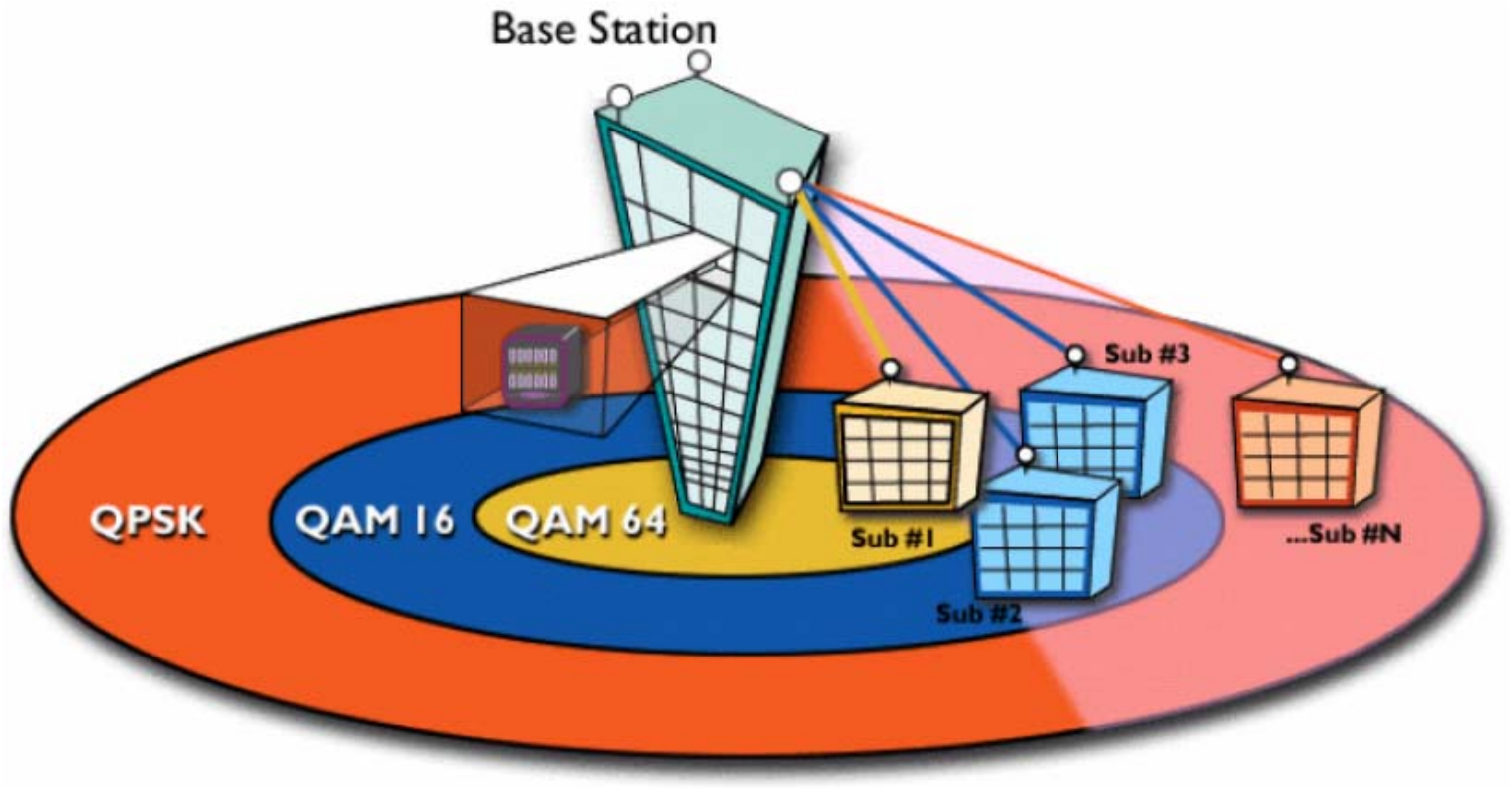


FIGURE 1: *The orthogonal nature of OFDM efficient use of bandwidth.*

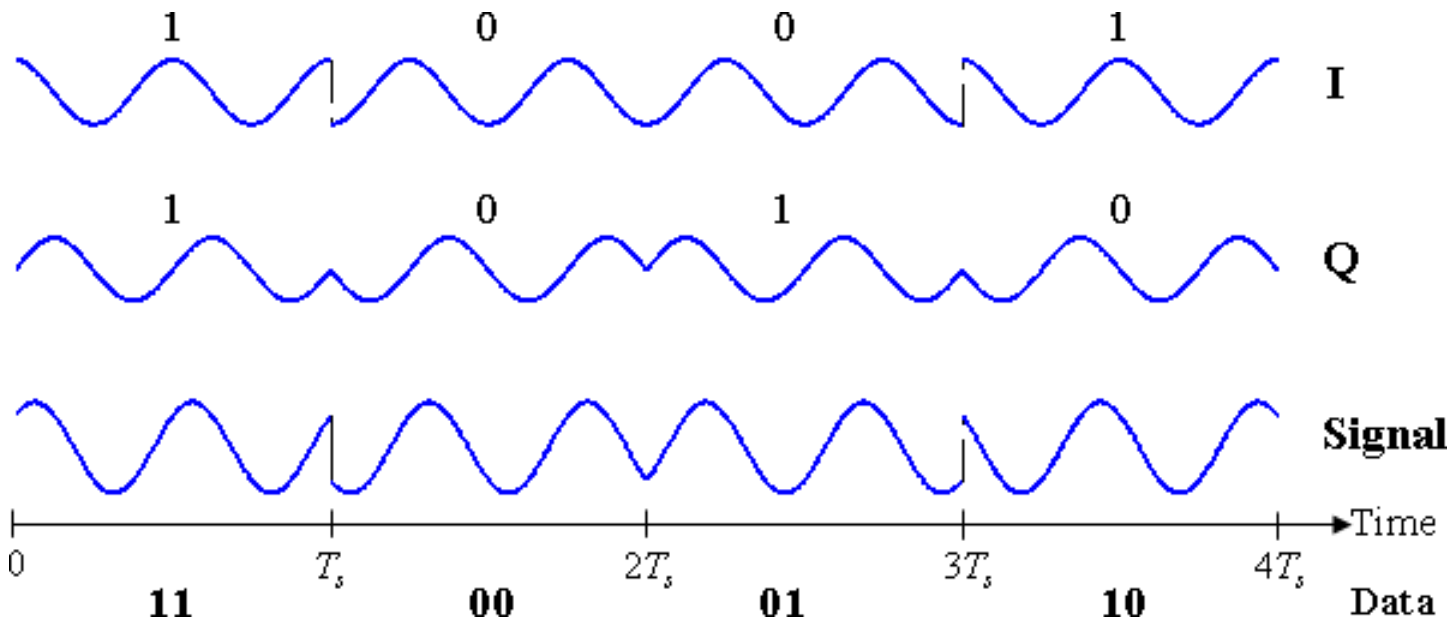
Adaptive Modulation



Modulation and coding scheme may be adjusted individually to each Subscriber Station (SS) on a burst-by-burst basis.

PSK

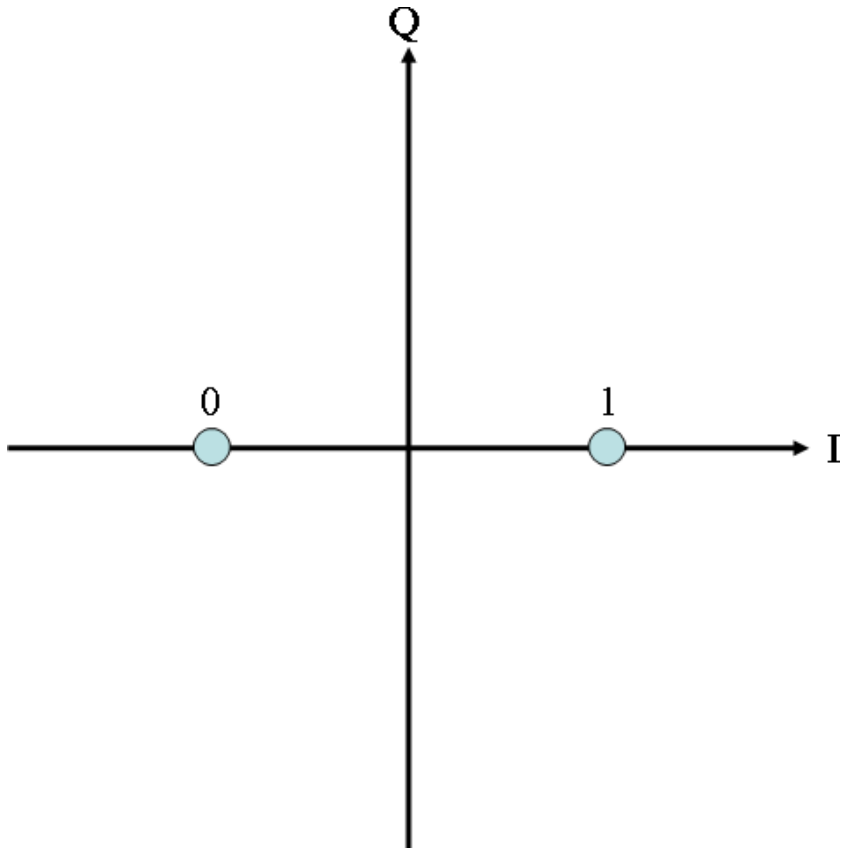
- Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).



BPSK

- 2-PSK
- 1bit/symbol

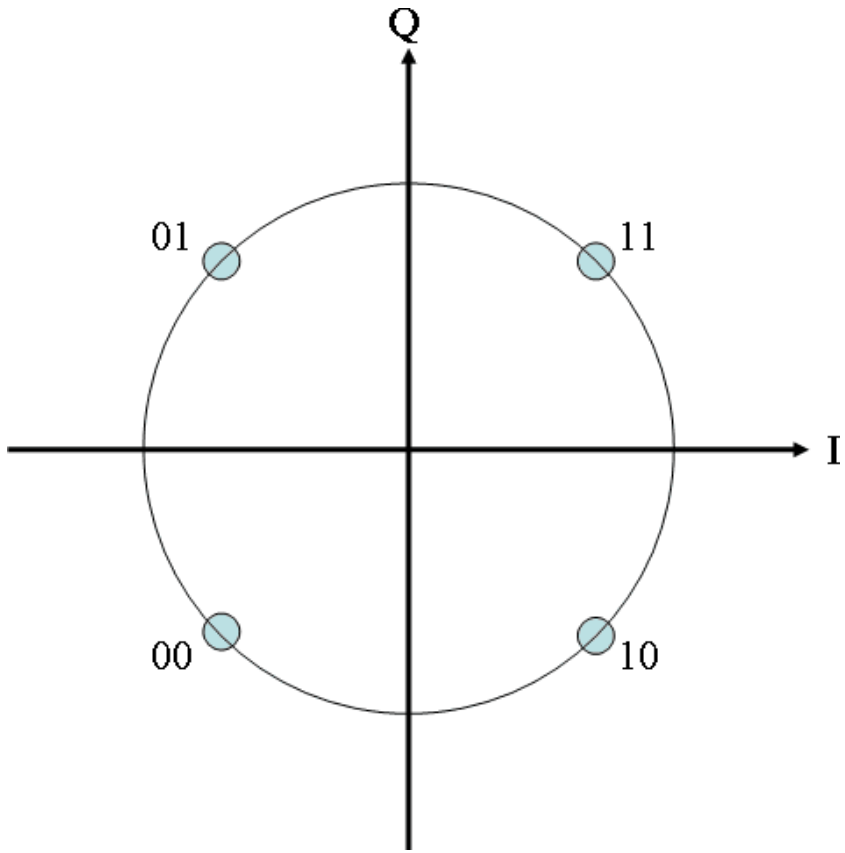
- BPSK is the simplest form of PSK.
- It is unsuitable for high data-rate applications



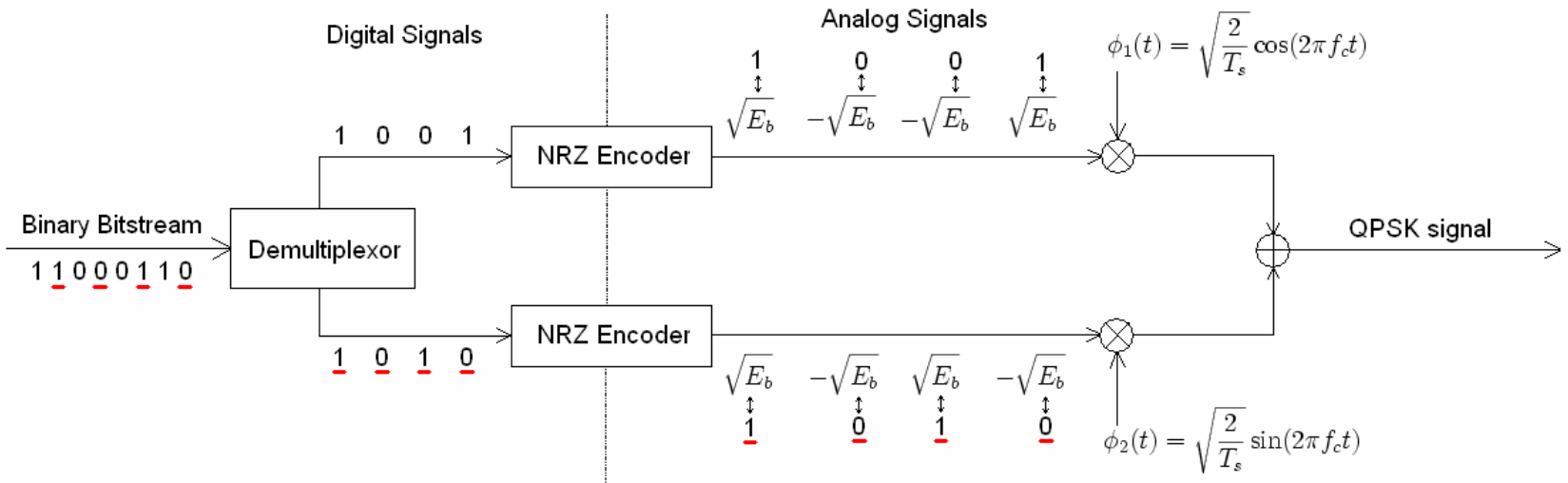
QPSK

- quaternary PSK
- quadriphase PSK
- 4-PSK
- 2bits/symbol

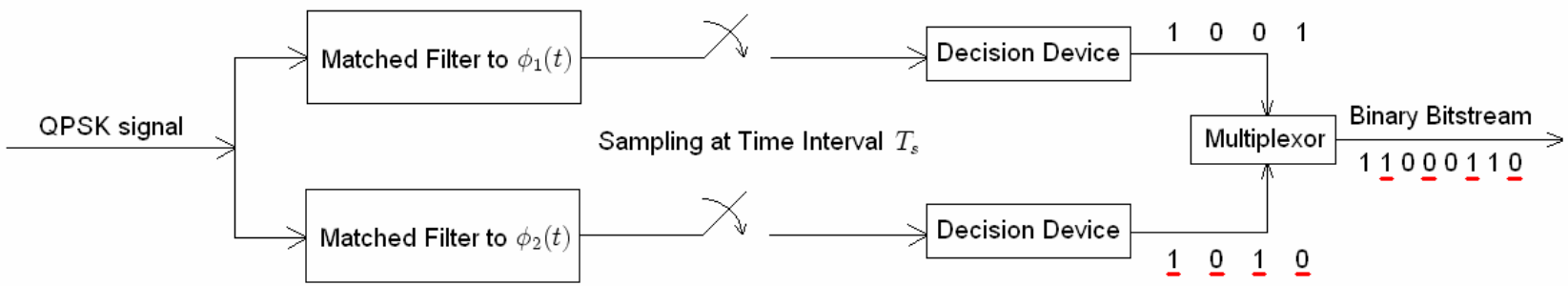
- QPSK uses four points on the constellation diagram, uniform angular spaced around a circle.



QPSK Circuits



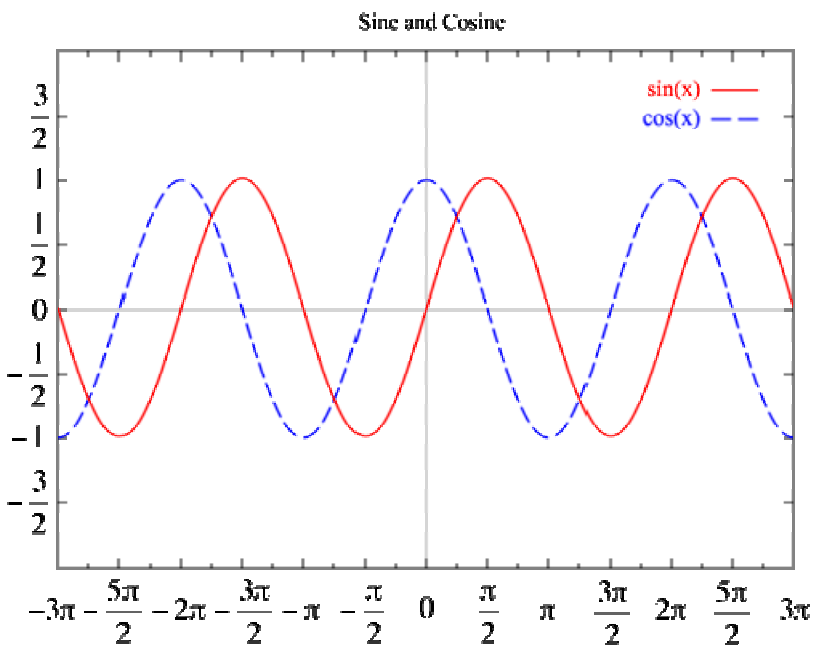
(a) QPSK transmitter structure



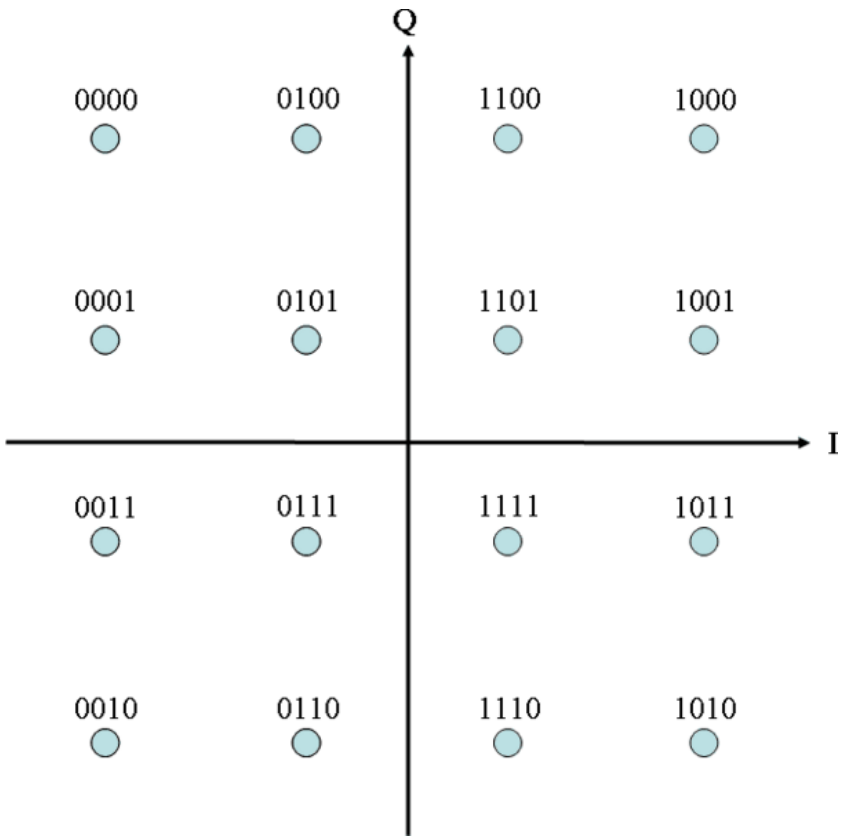
(b) QPSK receiver structure

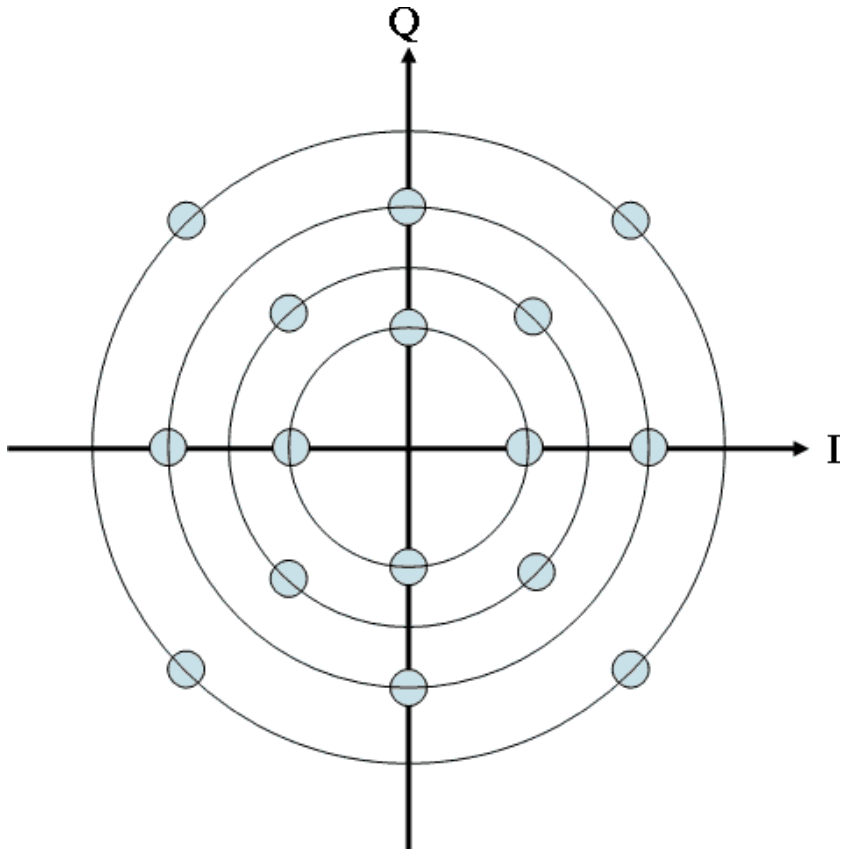
QAM

- Quadrature amplitude modulation (QAM) is a modulation scheme which conveys data by changing (modulating) the amplitude of two carrier waves.
- These two waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers.



Rectangular v.s. Non-rectangular



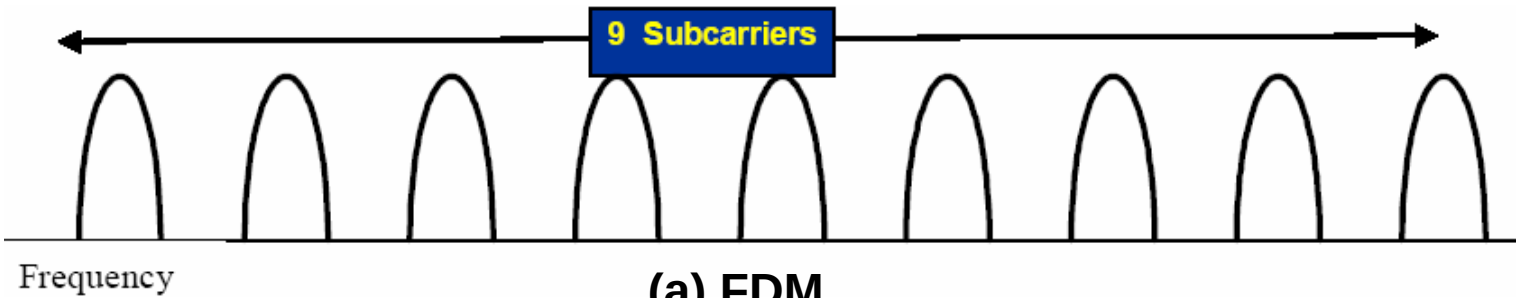


- Easy implementation

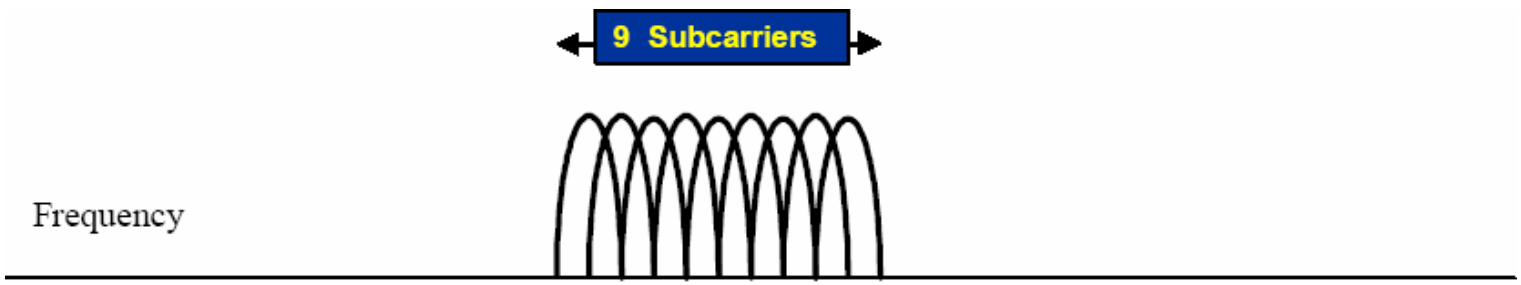
- Energy efficiency
- High SNR

OFDM

- Orthogonal frequency-division multiplexing (OFDM) is a transmission technique based upon the idea of frequency-division multiplexing (FDM).

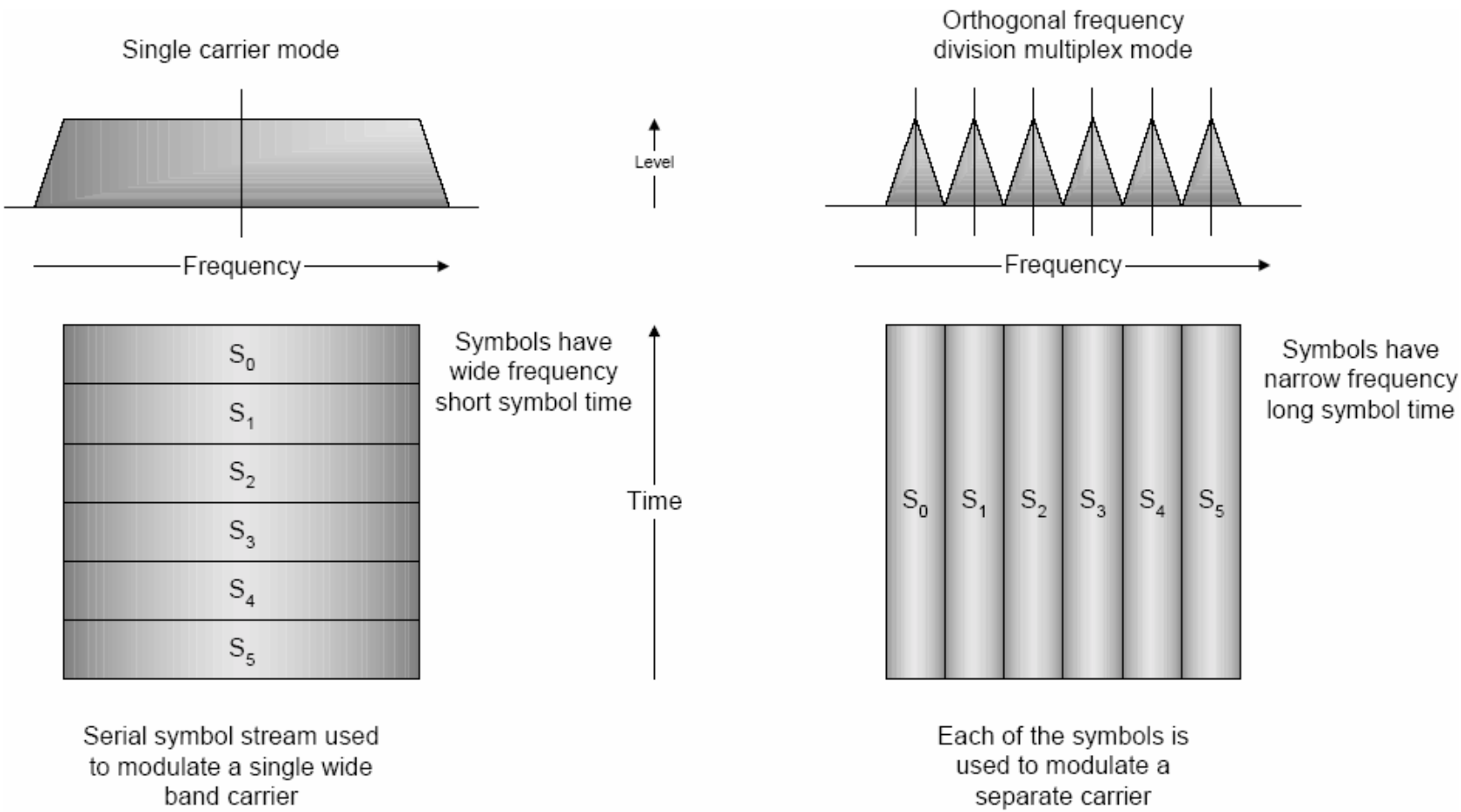


(a) FDM



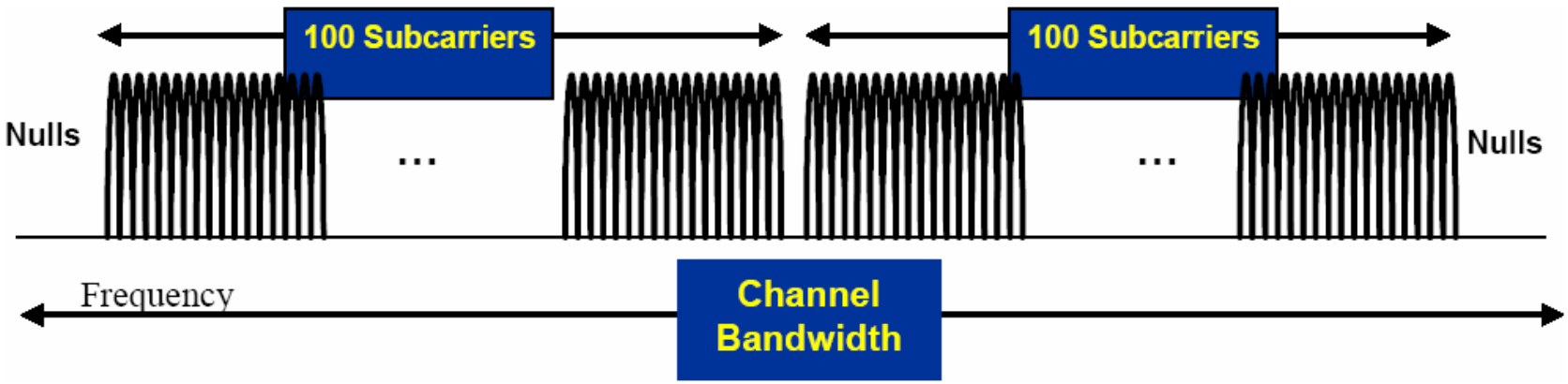
(b) OFDM

SC v.s. OFDM


Single carrier mode
Orthogonal frequency division multiplex mode
Level
Frequency
Frequency
S_0
S_1
S_2
S_3
S_4
S_5
Symbols have wide frequency short symbol time
Time
Symbols have narrow frequency long symbol time
Serial symbol stream used to modulate a single wide band carrier
Each of the symbols is used to modulate a separate carrier
Serial datastream converted to symbols, (each symbol can represent 1 or more data bits)

WiMAX OFDM

- 192 data subcarriers + 8 pilot subcarriers + 56 nulls

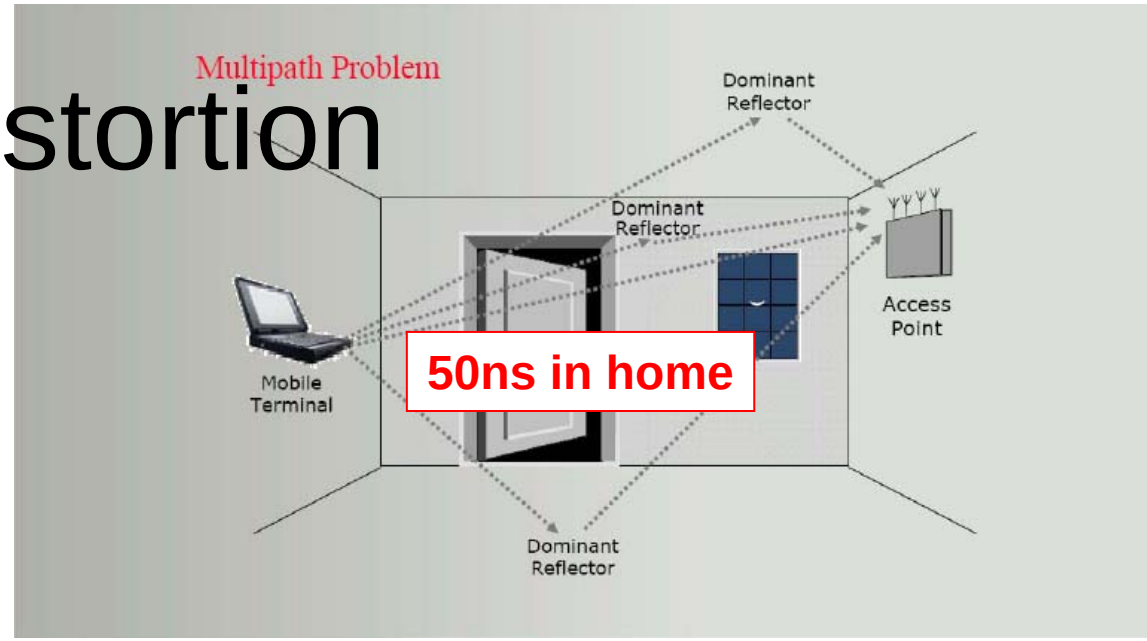


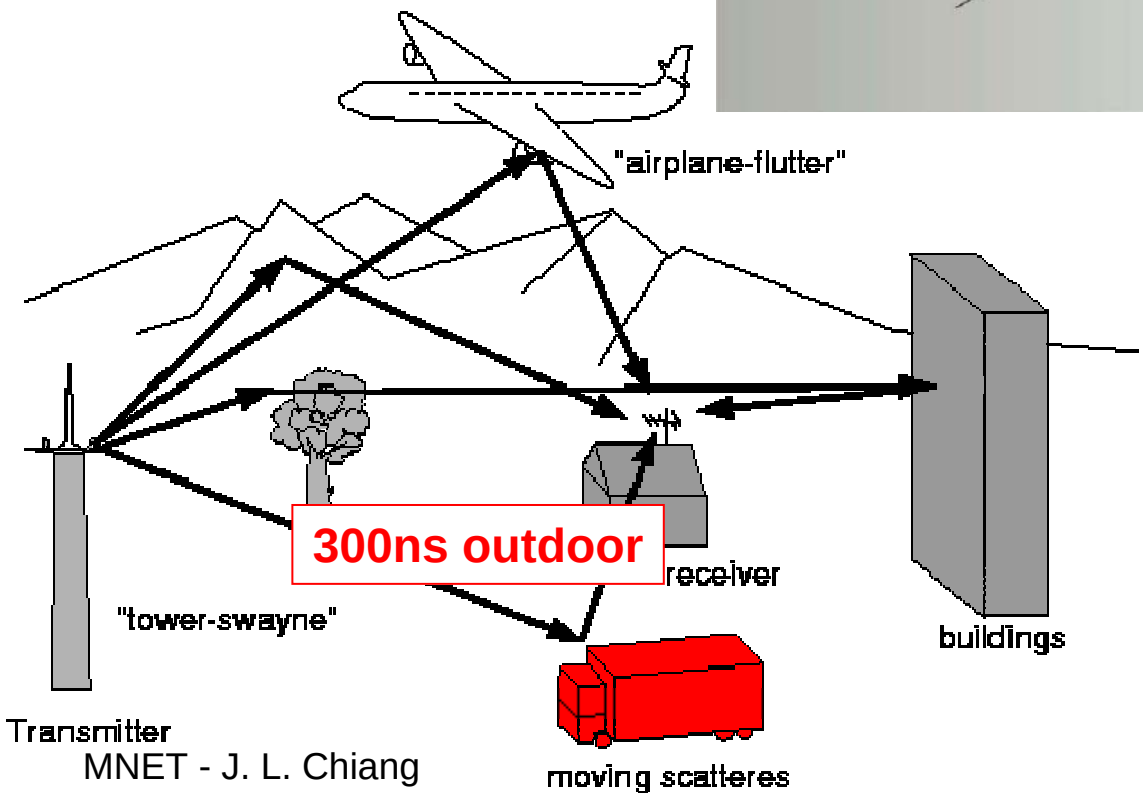
OFDM Features

- Orthogonal frequency-division multiplexing (OFDM) is a method of digital modulation in which a signal is split into several narrowband channels at different frequencies.
  - multiple signals are sent out at the same time, but on different frequencies

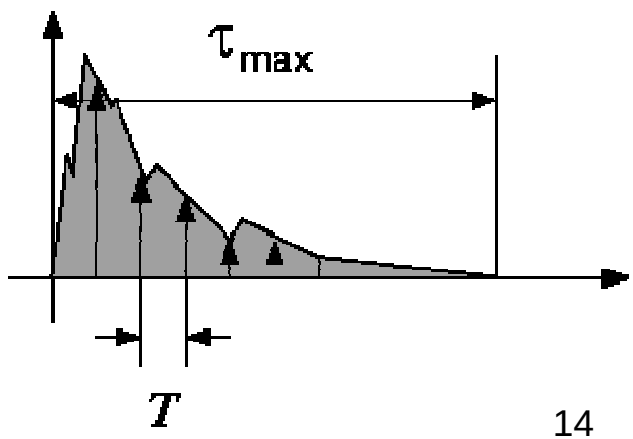
- Benefits of OFDM
  - High spectrum efficiency
  - Lower multipath distortion
  - Resiliency to RF interference

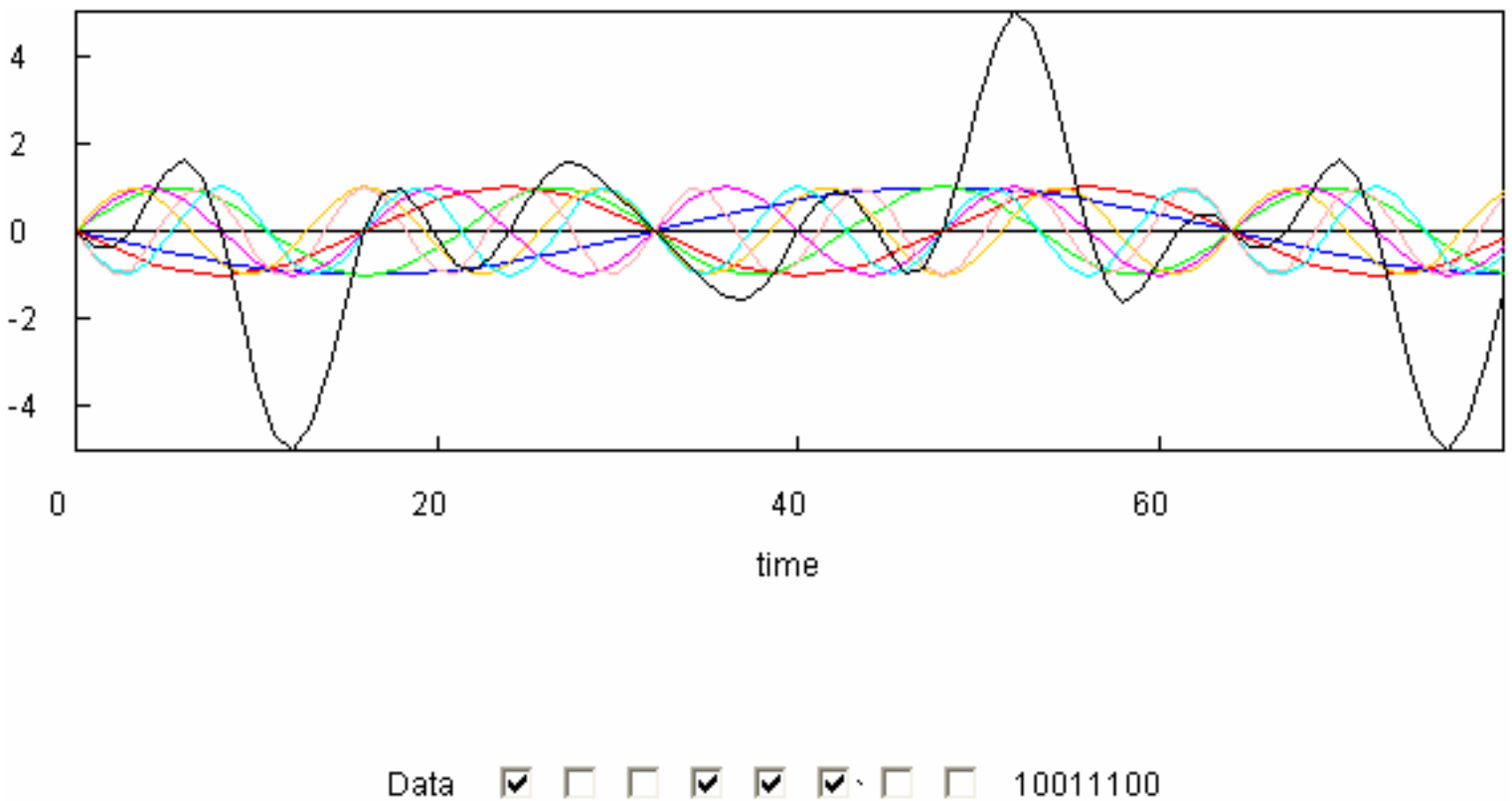
Multipath Distortion





cir: channel impulse response




4
2
0
-2
-4
0
20
40
60
time
Data
10011100

OFDM Applications

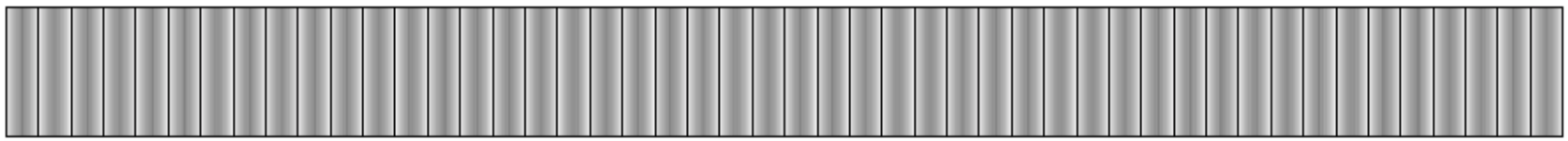
- OFDM is increasingly chosen as the modulation for various applications due to its spectral efficiency and inherent robustness to channel impairments.
  - DAB(Digital Audio Broadcast)
  - ADSL(Asymmetric digital subscriber)
  - DVB-T(Digital Video Broadcast - Terrestrial digital TV)
  - IEEE Wireless LAN (802.11a/g)
  - ETSI HiperLAN/2
  - UWB(Ultra WideBand)

WiMAX Sub-Channelization

- Sub-channeling concentrates the transmit power into fewer OFDM carriers.

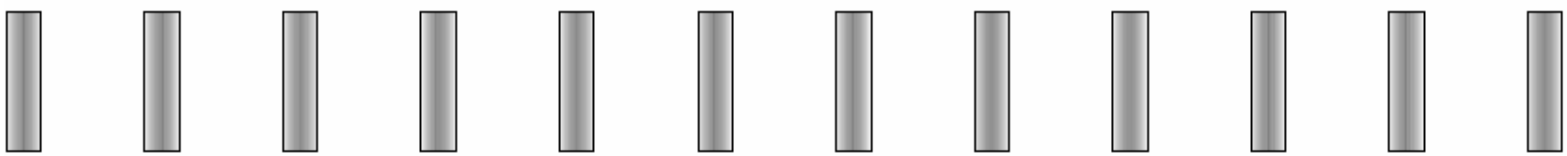
- Benefits of Sub-channelization
  - Extend the reach of the system
  - Overcome the building penetration losses
  - Reduce the power consumption of the CPE

Sub-Channelization



Transmitted downstream OFDM spectrum from the base station, each slot represents a RF carrier

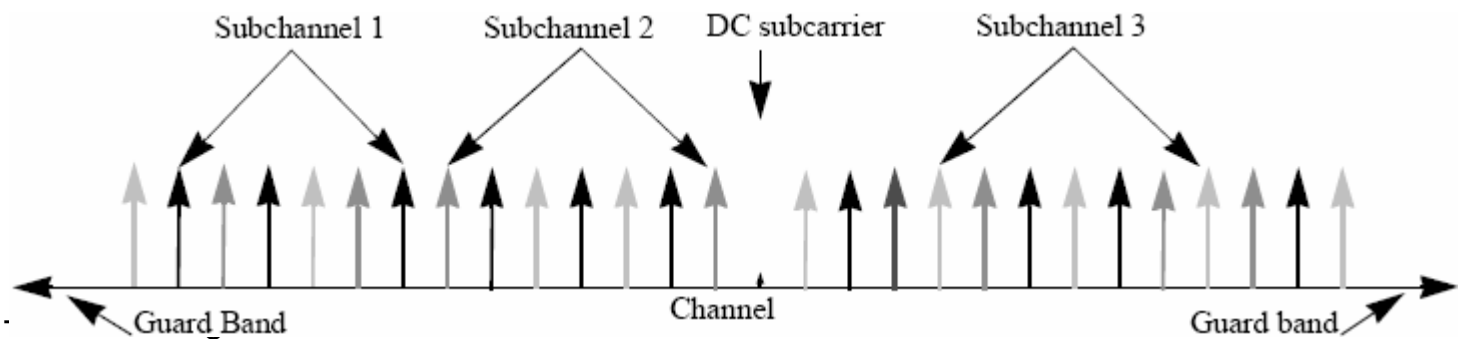
Transmitted upstream OFDM spectrum from the CPE, all carriers are transmitted but at a quarter of the level of the base station, hence the range will be less



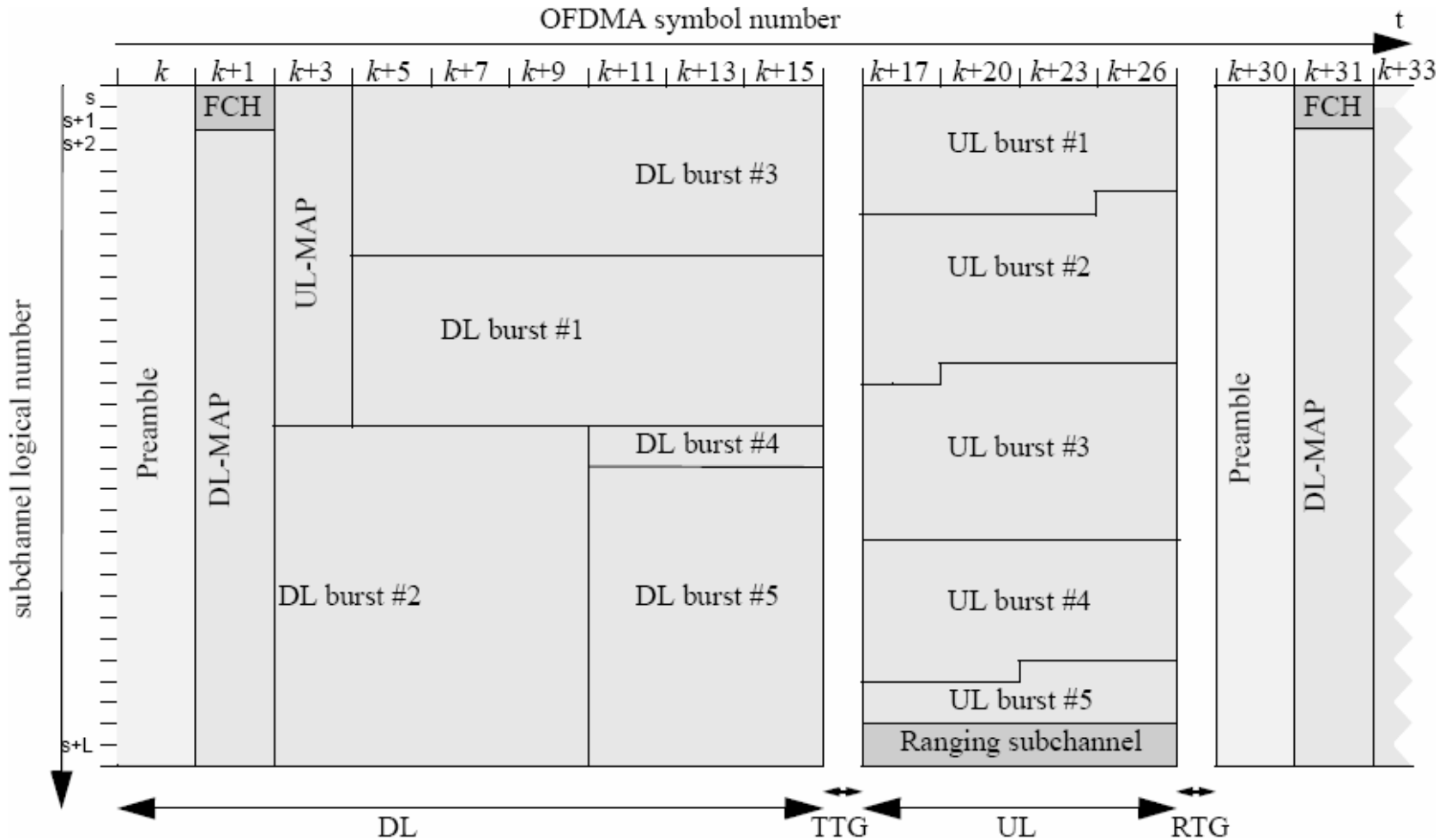
Transmitted upstream OFDM spectrum from the CPE using only a quarter of the carriers, but at the same level as the base station, hence the range will be the same with a quarter of the capacity

OFDMA

- Orthogonal Frequency Division Multiple Access (OFDMA) assigns a subset of subcarriers to individual users.
  - Functions essentially as OFDM-FDMA
  - OFDMA is the “multi-user” version of OFDM
  - Each OFDMA user transmits symbols using subcarriers that remain orthogonal to those of other users
  - More than one subcarrier can be assigned to one user to support high rate applications
  - Allows simultaneous transmission from several users ⇒ better spectral efficiency



WiMAX OFDMA Frame

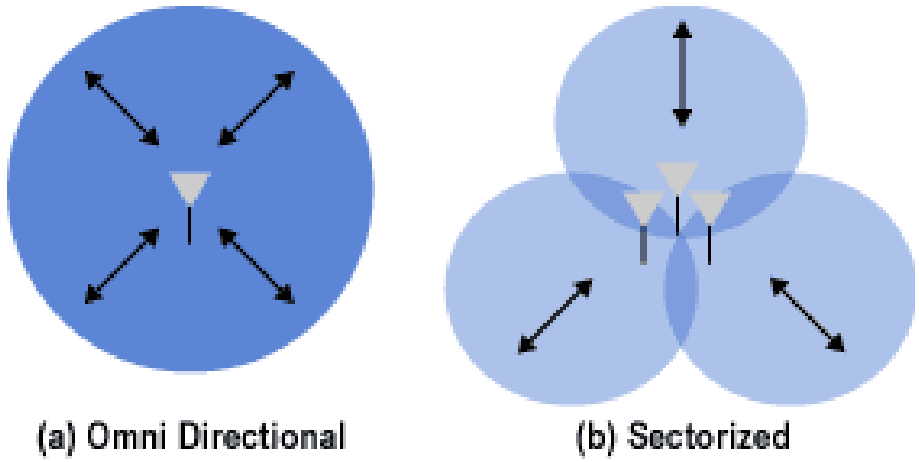


AAS

- Adaptive Antenna Systems (AASs) have beamforming properties that can steer the focus to a particular direction or directions on both transmitting and receiving.

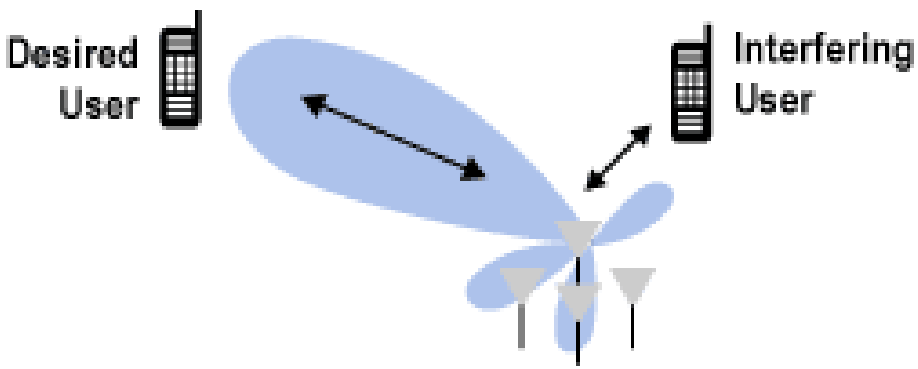
- Benefits of AAS
  - High system gain for maximum coverage and availability
  - Use for extended range or increased capacity
  - Reduction in overall levels of interference
  - SS can be omni-directional for low cost

Antenna Systems



(a) Omni Directional

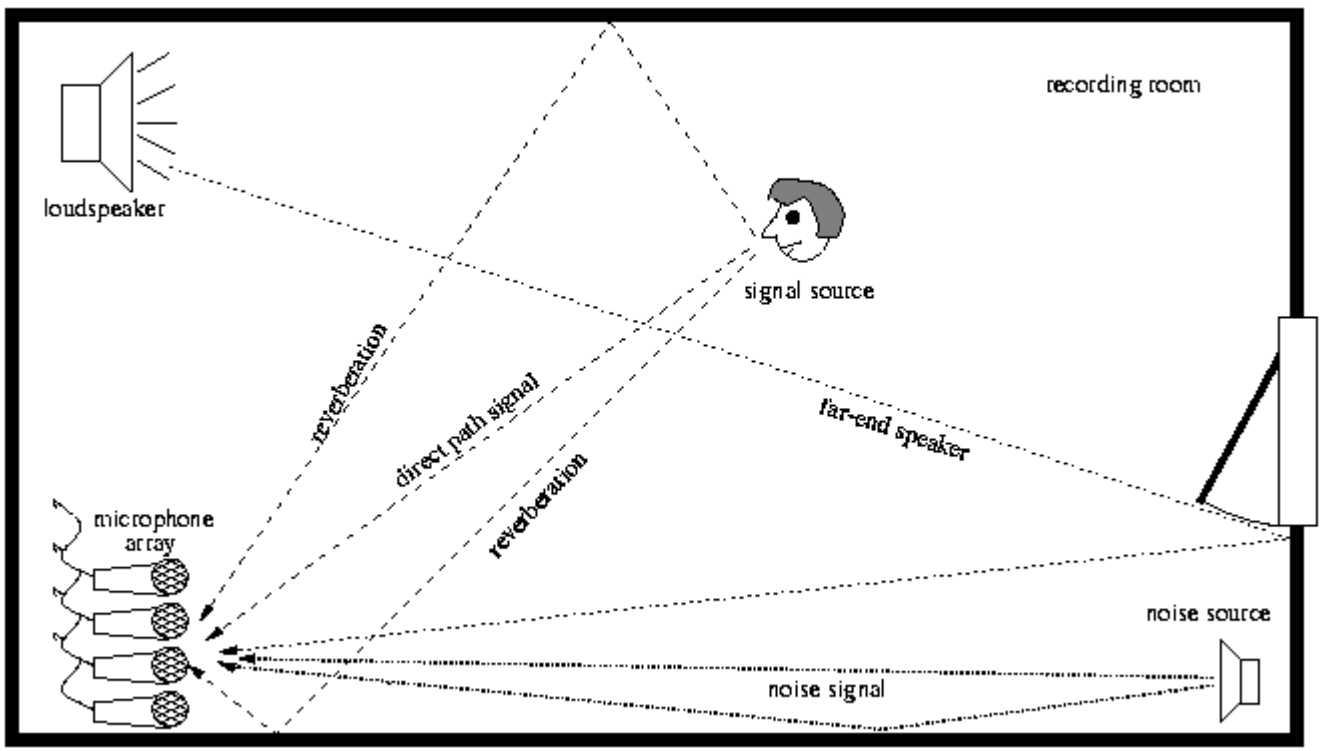
(b) Sectorized



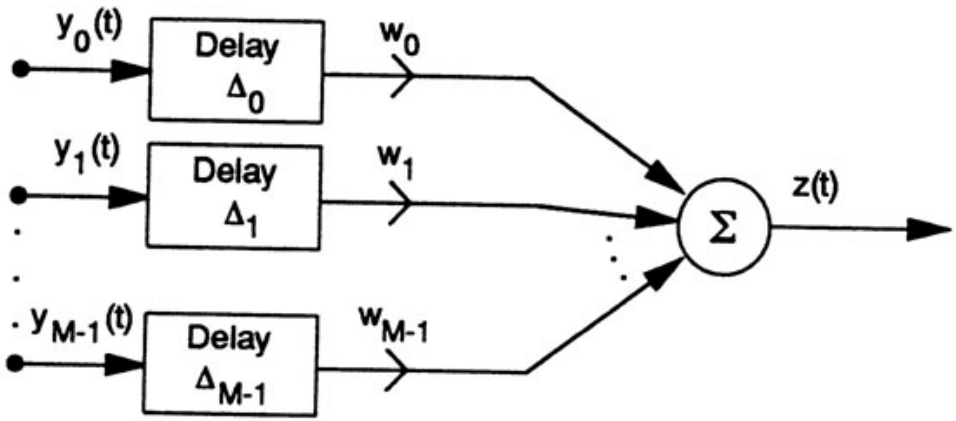
(c) Smart Antennas—Beamforming

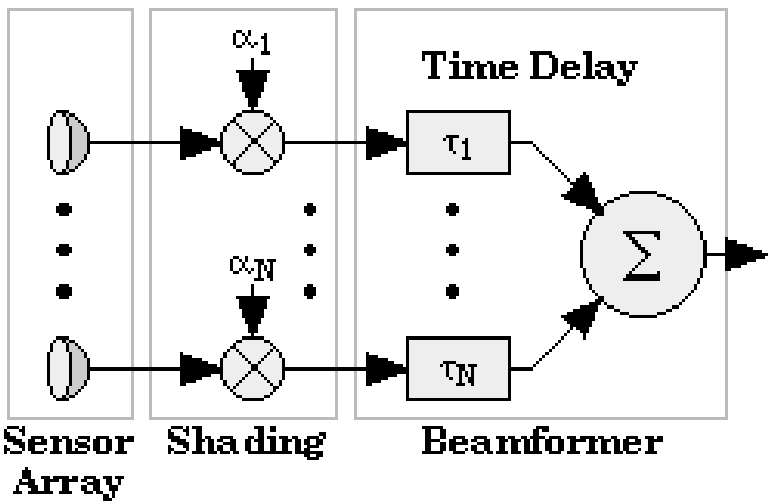
Beamforming

- By using a microphone array, the different spatial characteristics of speech and noise can be exploited.

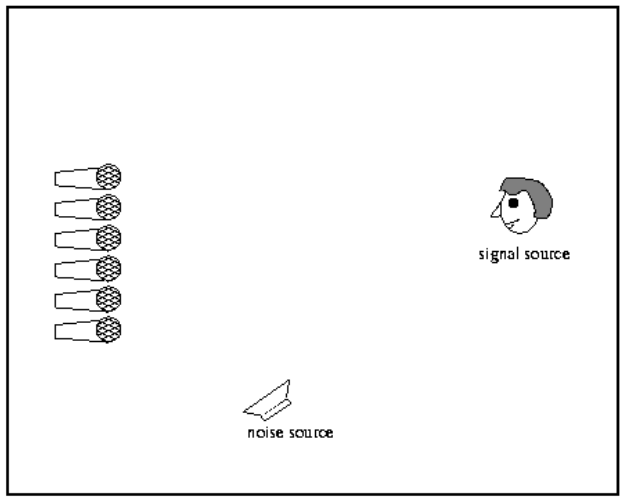


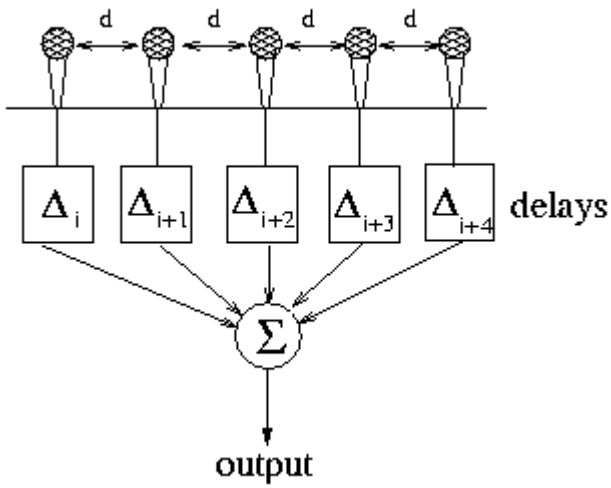
Delay-and-Sum Beamformer

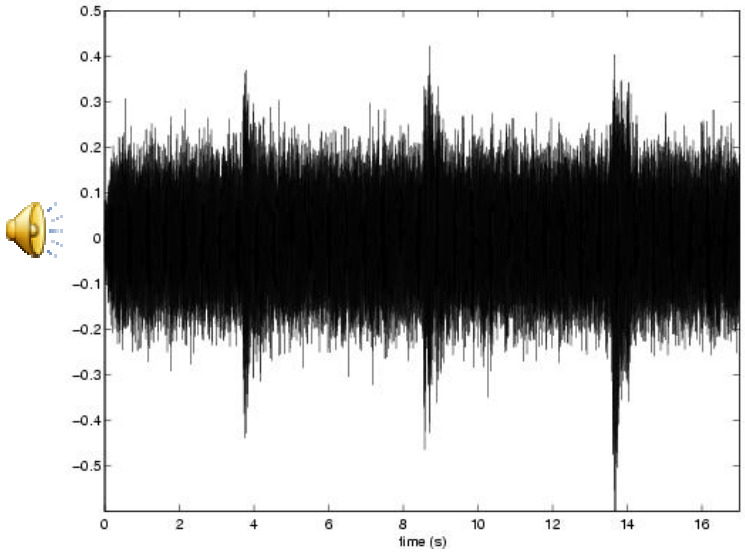


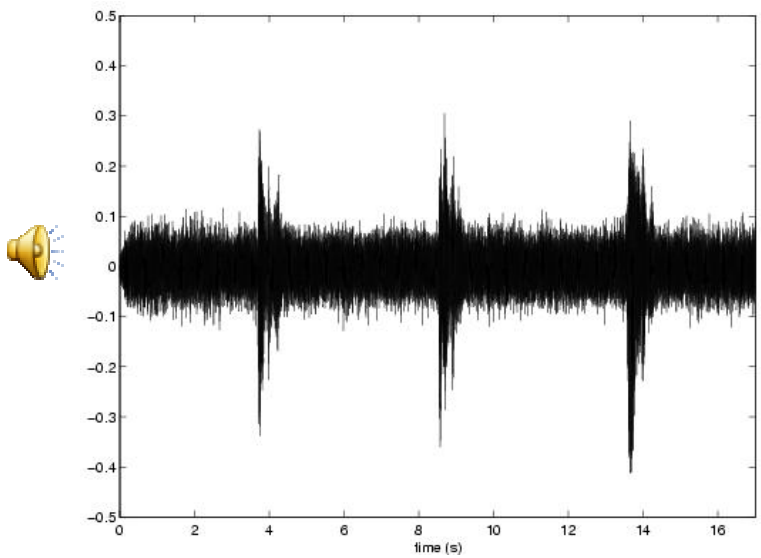


Experiment

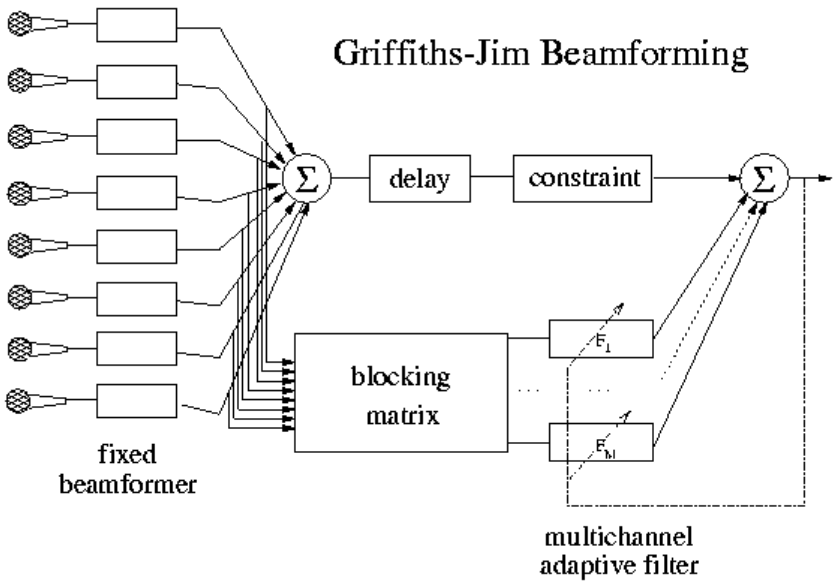

signal source
noise source

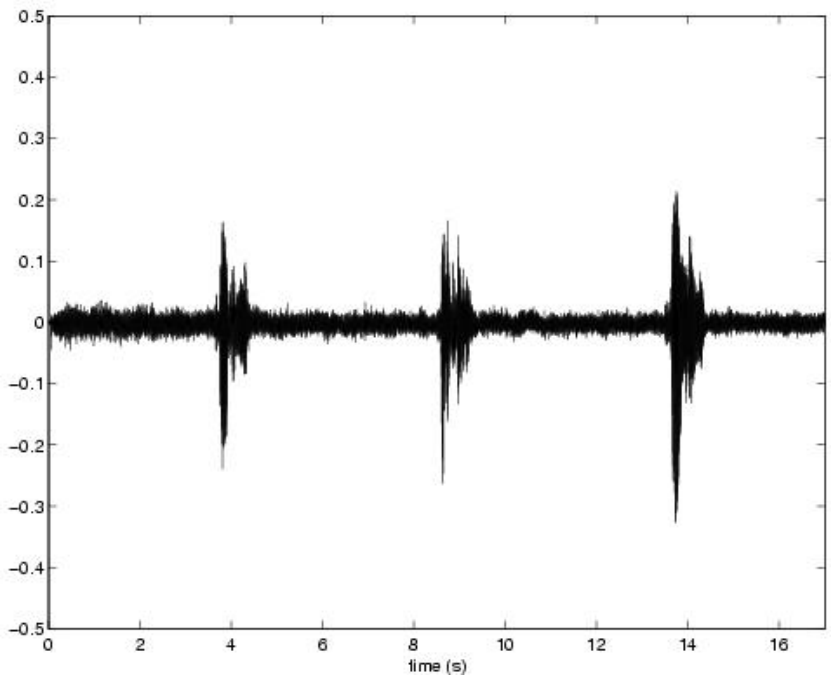

d
d
d
d
Δ i
Δ i+1
Δ i+2
Δ i+3
Δ i+4
delays
Σ
output


0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
0
2
4
6
8
10
12
14
16
time (s)


0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
0
2
4
6
8
10
12
14
16
time (s)

Experiment


Griffiths-Jim Beamforming
delay
constraint
blocking
matrix
fixed
beamformer
multichannel
adaptive filter


0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
2
4
6
8
10
12
14
16
time (s)

Summary

- WiMax (WirelessMAN-OFDMA) becomes a competitor against 3GPP 3.5G(HSDPA, High Speed Downlink Packet Access) for 4G wireless technology.
  - WiMAX will take over the 3G networks and become the 4G wireless technology – AT&T.
- OFDM/OFDMA and smart antenna systems are key technologies to drive the 4G wireless systems.

Summary

Technology	Standard	Usage	Throughput	Range	Frequency
UWB	802.15.3a	WPAN	110-480 Mbps	Up to 30 feet	7.5 Ghz
Wi-Fi*	802.11a	WLAN	Up to 54 Mbps	Up to 300 feet	5 Ghz
Wi-Fi	802.11b	WLAN	Up to 11 Mbps	Up to 300 feet	2.4 Ghz
Wi-Fi	802.11g	WLAN	Up to 54 Mbps	Up to 300 feet	2.4 Ghz
WiMAX	802.16d	WMAN	Up to 75 Mbps (20 Mhz BW)	Typical 4-6 miles	Sub 11 Ghz
WiMAX	802.16e	Mobile WMAN	Up to 30 Mbps (10 Mhz BW)	Typical 1-3 miles	2-6 Ghz
WCDMA/UMTS	3G	WWAN	Up to 2 Mbps (Up to 10 Mbps with HSDPA technology)	Typical 1-5 miles	1800, 1900, 2100 Mhz
CDMA2000 1 x EV-DO	3G	WWAN	Up to 2.4 Mbps (typical 300-600 Kbps)	Typical 1-5 miles	400, 800, 900, 1700, 1800, 1900, 2100 Mhz
Edge	2.5G	WWAN	Up to 348 Kbps	Typical 1-5 miles	1900 Mhz

References

- The IEEE 802.16 Working Group on Broadband Wireless Access Standards, http://www.ieee802.org/16/
- WiMAX Forum, http://www.wimaxforum.org/home
- Intel, http://www.intel.com/go/wimax
- Wikipedia, http://en.wikipedia.org/wiki/Main_Page
- Sky DSP, http://www.skydsp.com/index.htm
- Wi-LAN Inc., http://www.wi-lan.com/index.html