Satellite Communications using Ultra Wideband(UWB) Signals

March 3, 2004

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Background (1)

- UWB (Ultra WideBand) is expected to realize high speed data transmission for terrestrial short distance communications.
- The standardization activity of the UWB radio system was started in IEEE802.15.
- UWB devices have good features for terminals such as simple hardware configuration, low power consumption, etc.

Background (2)

- Effective use of an electric wave is desired also in the satellite communication.
- Assuming UWB signal can be overlaid on other system spectrum without vast interference.

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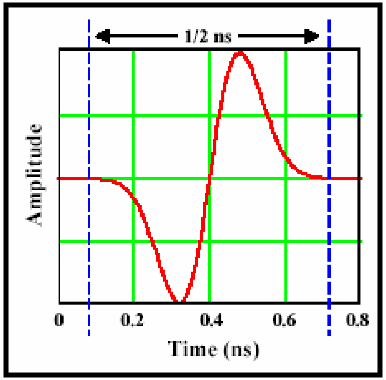
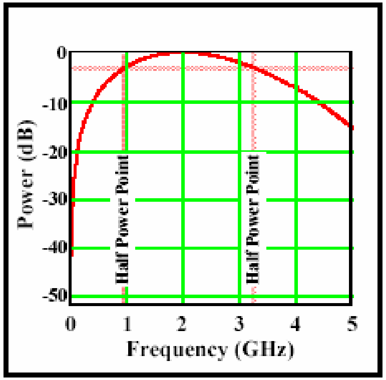
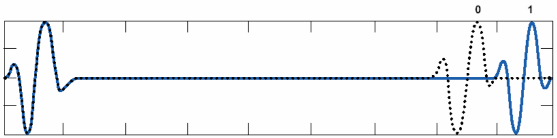
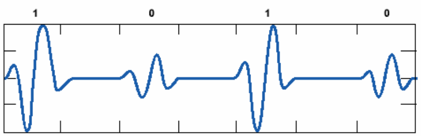
- Satellite communications using UWB signals have possibility to enable new services and new markets.
- Initial results on link budget calculation and estimation of signal transmission speed is presented.

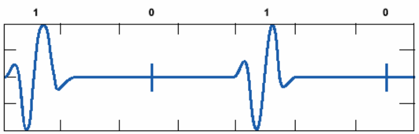
What's UWB ? (Short pulse type)







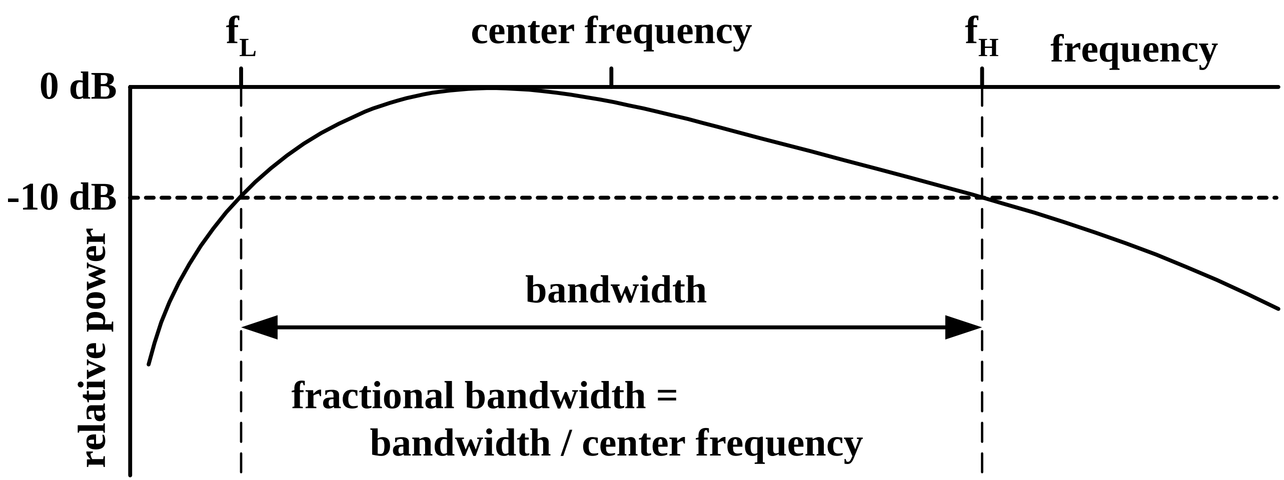




- Short duration pulse has wide bandwidth.
- Data is encoded by pulse modulation such as PPM or PAM.

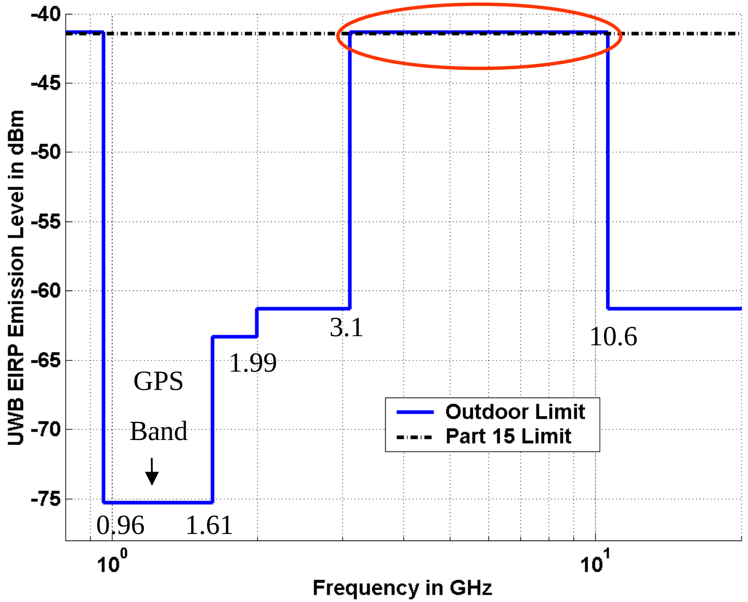
UWB regulation of FCC (1)

- Specifications for communication devices using UWB
  - BANDWIDTH :
    Fractional bandwidth equal to or greater than 0.2, or bandwidth equal to or greater than 500 MHz.



UWB regulation of FCC (2)

- RADIATED EMISSIONS :
  0.96 - 1.61 GHz < -75.3 dBm/MHz
  1.61 - 1.99 GHz < -63.3 dBm/MHz
  1.99 - 3.1 GHz < -61.3 dBm/MHz
  3.1 - 10.6 GHz < -41.3 dBm/MHz
  10.6 GHz - < -61.3 dBm/MHz

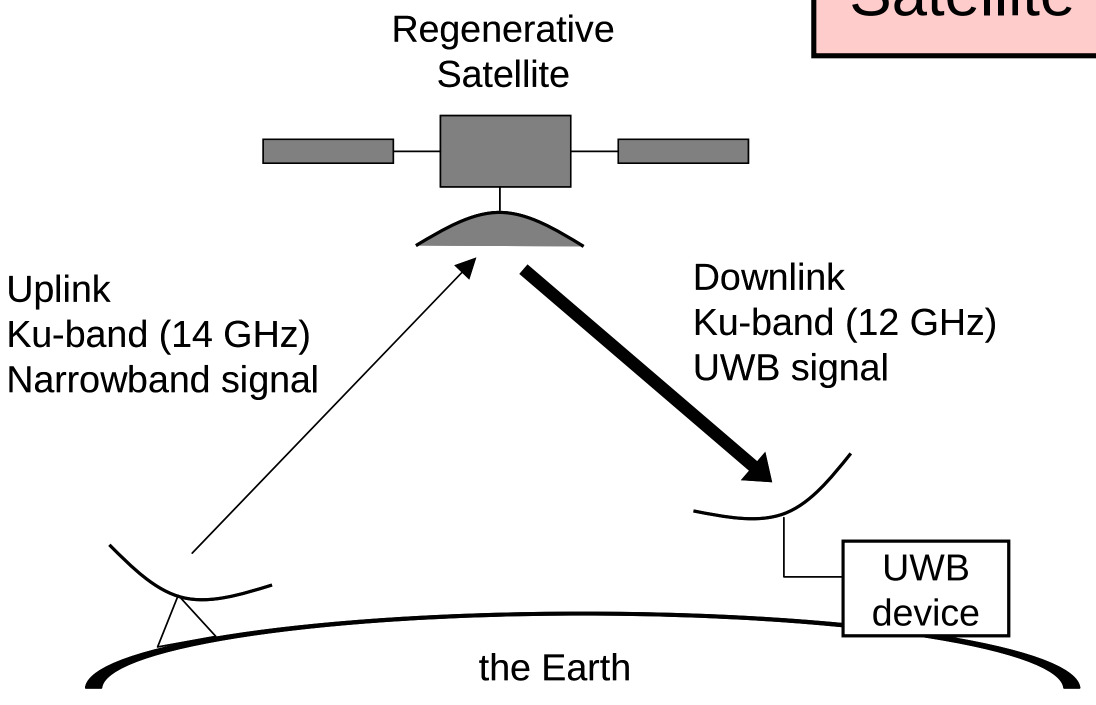


- PEAK LEVEL OF EMISSIONS :
  A peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission is 0 dBm EIRP.

Concept of Satellite UWB

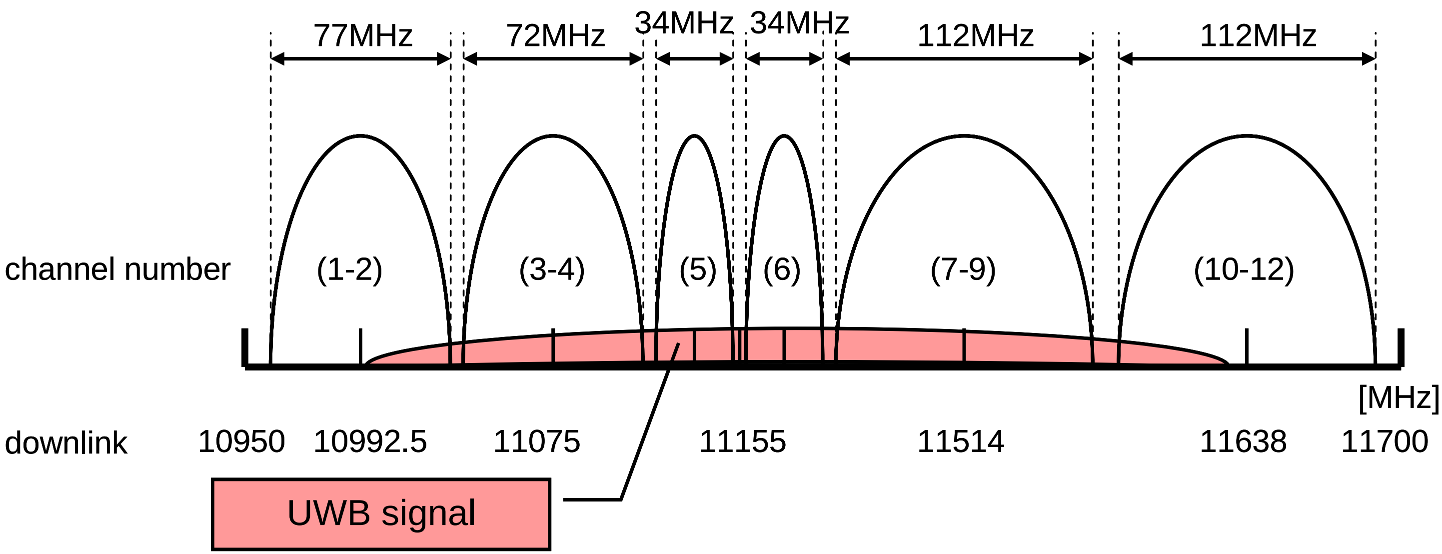
- Adopt UWB in Satellite Communications
- Using Ku-band FSS

Satellite UWB



Satellite UWB spectrum

- Overlaying onto existing systems



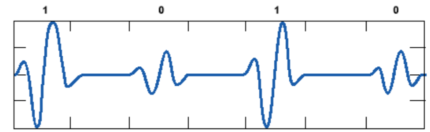
Link budget

- Received power level is much smaller than signal level of terrestrial UWB.

Center frequency	12	GHz
Bandwidth	500	MHz
Transmission power	20.3	dBW
Satellite antenna diameter	1.27	m
Satellite antenna gain (efficiency = 60%)	41.8	dBi
EIRP	65.1	dBm/MHz
Link margin	5	dB
Rain margin	3	dB
Path loss to the earth surface (at 12 GHz)	205.2	dB
Power density at earth surface	**-148.1**	dBm/MHz

3m from the **terrestrial** UWB transmitter is **-100.0** dBm/MHz

Throughput using PAM (1)



- Employ PAM (Pulse Amplitude Modulation)
- Symbol error probability of M-ary PAM

$$P_M = \frac{M-1}{M} erfc\left(\sqrt{\frac{3}{M^2-1} \times \frac{E_s}{N_0}}\right)$$

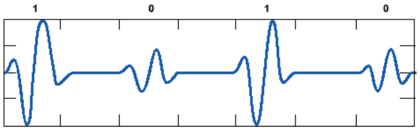
E_s/N_0 : signal power per symbol to noise power density ratio

- Bit error probability

$$P_b = \frac{1}{k} P_M$$

k : the number of bits transmitted in a symbol

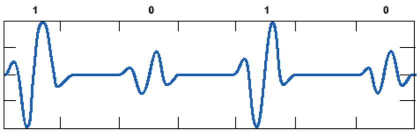
Throughput using PAM (2)



- Required E_s/N_0 for BER = 10^{-3}

M	Required E_s/N_0 [dB]
2	7
4	13.75
8	19.77
16	25.5

Throughput using PAM (3)



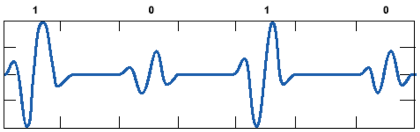
- E_s/N_0 presented by pulse repetition frequency

$$E_s / N_0 = P_{ave} T_p / N_0 = [P_{sd} / N_0] \times [B_s / B_p]$$

P_{ave}: Average received power
T_p: Pulse repetition period
P_{sd}: Average power spectral density
B_s: Equivalent occupied bandwidth
B_p: Pulse repetition frequency

$$B_p = [P_{sd} / N_0] \times B_s / N_F / [E_s / N_0]$$

Throughput using PAM (4)



- Achievable throughput
  - Assuming free-space propagation

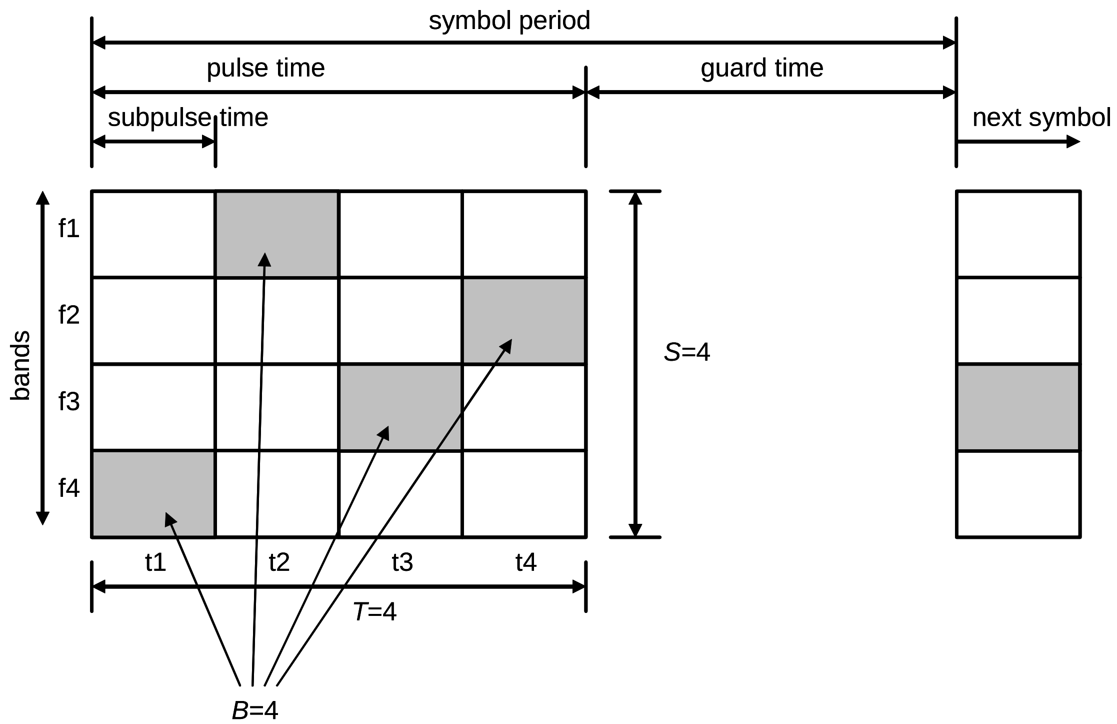
P_{sd} = -208.1 [dBm/Hz]
B_s = 500 [MHz]
N_0 = -174 [dBm/Hz] (at room temperature)
N_F = 6 [dB]

[bit/s]

	2-ary	4-ary	8-ary	16-ary
0 [dBi] (Same as terrestrial UWB)	9.96 k	4.21 k	1.58 k	563
5.0 [dBi] (Patch antenna)	31.5 k	13.3 k	4.99 k	1.78 k
19.8 [dBi] (10 cm dish)	951 k	402 k	151 k	53.7 k
33.7 [dBi] (50 cm dish)	23.3 M	9.87 M	3.70 M	1.32 M
39.8 [dBi] (1 m dish)	95.1 M	40.2 M	15.1 M	5.37 M

Multiband-UWB signal

- Symbol structure example of MB-UWB



Throughput using MB-UWB (1)

- Subpulse error probability of MB-UWB

$$P_s = 4(S-1)Q\left(\sqrt{\frac{2E_{sp}}{N_0}}\right)$$

S: Number of frequency bands
E_{sp}: Energy per subpulse
N_0: Noise spectral density

$$E_s = E_{sp} \times S$$

- Required E_s/N_0 for subpulse error rate of 10^{-3}

S	Required E_s/N_0 [dB]
4	14.5
8	18

Throughput using MB-UWB (2)

- Pulse repetition frequency

$$B_p = [P_{sd} / N_0] \times B_s / N_F / [E_s / N_0]$$

- Achievable throughput

$$R = B_p \times \left[\log_2 (S!) + SP\right]$$

S: Number of frequency bands
P: Number of polarity bits

[bit/s]

	4-bands		8-bands	
	BPSK	QPSK	BPSK	QPSK
0 [dBi] (Same as terrestrial UWB)	15.2 k	22.3 k	18.4 k	28.4k
5.0 [dBi] (Patch antenna)	48.1 k	70.5 k	58.3 k	78.3 k
19.8 [dBi] (10 cm dish)	1.45 M	2.13 M	1.76 M	2.36 M
33.7 [dBi] (50 cm dish)	35.6 M	52.3 M	43.2 M	58.1 M
39.8 [dBi] (1 m dish)	145 M	213 M	176 M	236 M

Conclusion

- Possibility of satellite UWB is considered.
- Received signal power density at the earth's surface is much smaller than the signal level of the terrestrial UWB.
- High throughput can be realized by satellite UWB under our assumptions.
- The satellite UWB has possibility to enable new services, and is expected to open new markets.

Thank you !

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