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Submission Title: [Frequency Plan and PRF Proposal for TG4a]

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Abstract: [Frequency plan and PRF proposal for DS-UWB radios]

Purpose: [Proposal to harmonize some proposed frequency plans]

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Frequency Plan and PRF Proposal for TG4a

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Required PRF

- The low bound for PRF is ~10 MHz@500MHz for 90nm CMOS (0243-00-4a)

- What is the high bound for PRF?
  - Tradeoff among many parameters.
  - A small PRF is favorable if we want low complexity, low cost, and for good anti-multipath performance.
  - Among reasons for a large PRF, efficient use of FCC mask and quick acquisition time are on the top.

- PRF Proposed (Wisair, Wideband Access, Freescale, etc.)
  - 33 MHz, 66 MHz,
  - 15.4375, 30.875, 61.75
  - 13MHz, 26 MHz

Our PRF Proposal

- **Basic is 26 MHz with an option of 52 MHz.**
  - These values combined with our band plan can harmonize crystals of 24 MHz (12 MHz) and 26 MHz (13 MHz)!
- **Why 26 MHz is selected as basic?**
  - The reason we prefer a PRF over 20 MHz is to provide a data rate of several Mbps.
  - 26 MHz is the lowest value at hand to favor low PRF seeker.
- **Why 52 MHz is selected as options?**
  - To meet request for higher PRF and lower PRF.
  - Easy generation from basic PRF of 26 MHz.

Thoughts on Frequency Plan

- **Center frequency should be a product of PRF with an integer.**
  - **52 MHz multiply with an integer.**
- **Center frequency should be a integer product of basic crystals.**
  - **We mainly look at 24 MHz (12 MHz) and 26 MHz (13MHz) crystals.**
- **In case that the above conditions can't be met at a time, the center frequency should also be generated easily from the basic crystals of 24 MHz and 26 MHz.**

Additional Restriction on Frequency Band

- **The frequency band for WLAN in Japan (802.11j) is**

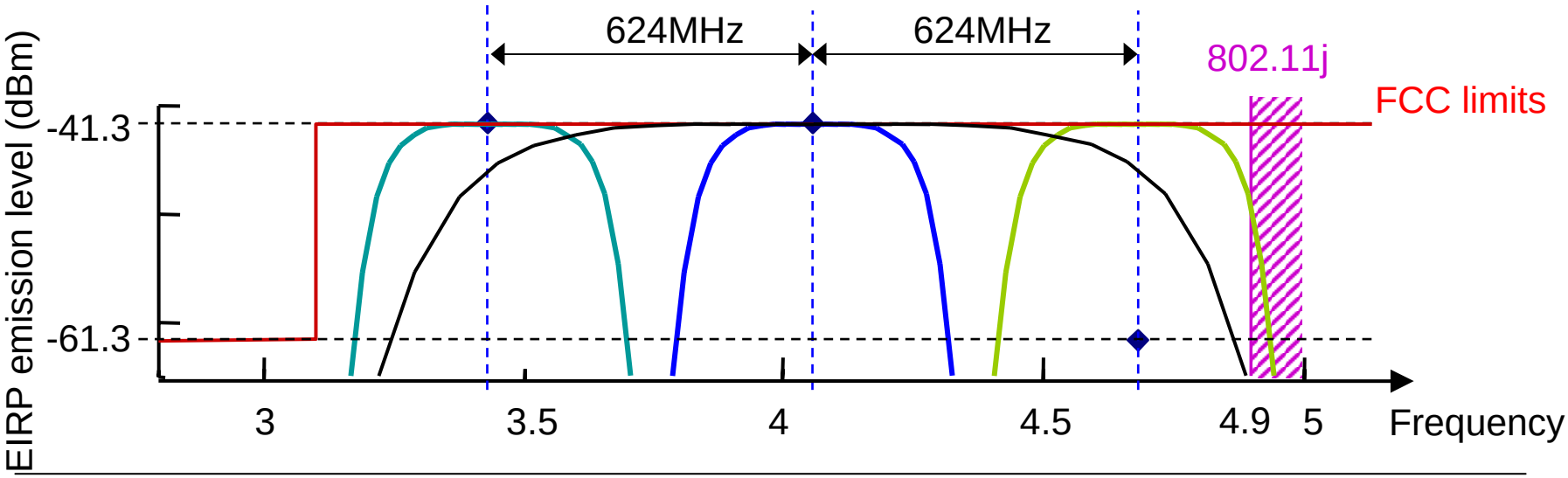
  4.9 ~ 5.0 GHz

- **FYI**
  - **The frequency bands under discussion in Japan for 4G mobile communication are**

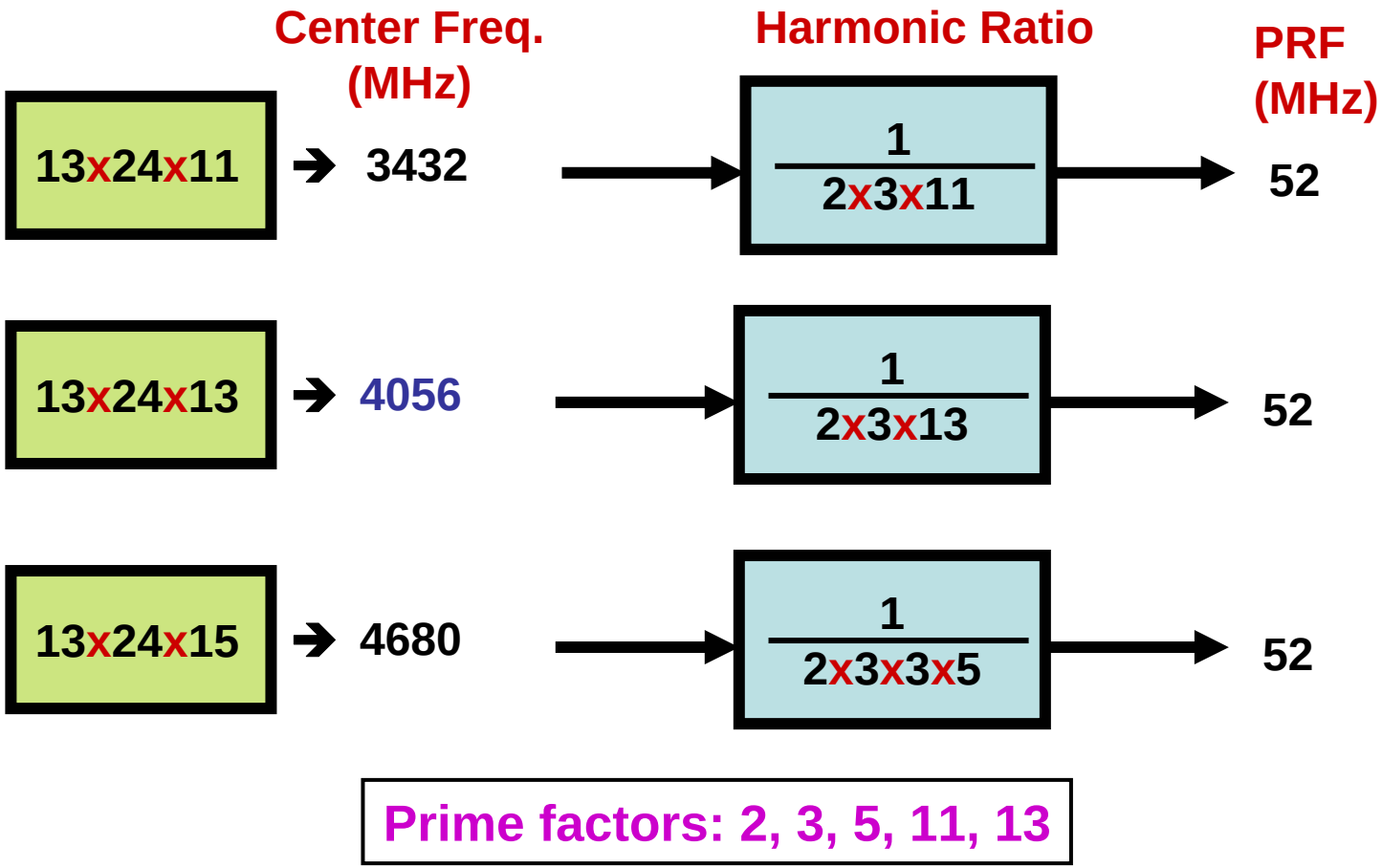
    3.6 – 4.2 GHz and 4.4 - 4.9 GHz

Frequency Plan (I)

Band No.	Bandwidth (MHz)	Low Freq. (MHz)	Center Freq. (MHz)	High Freq. (MHz)
1	>=500	3182	3432	3682
2 (mandatory)	>=500	3806	4056	4306
3	>=500	4430	4680	4930
4	>=1500	3306	4056	4806



PRF Flexibility (I)

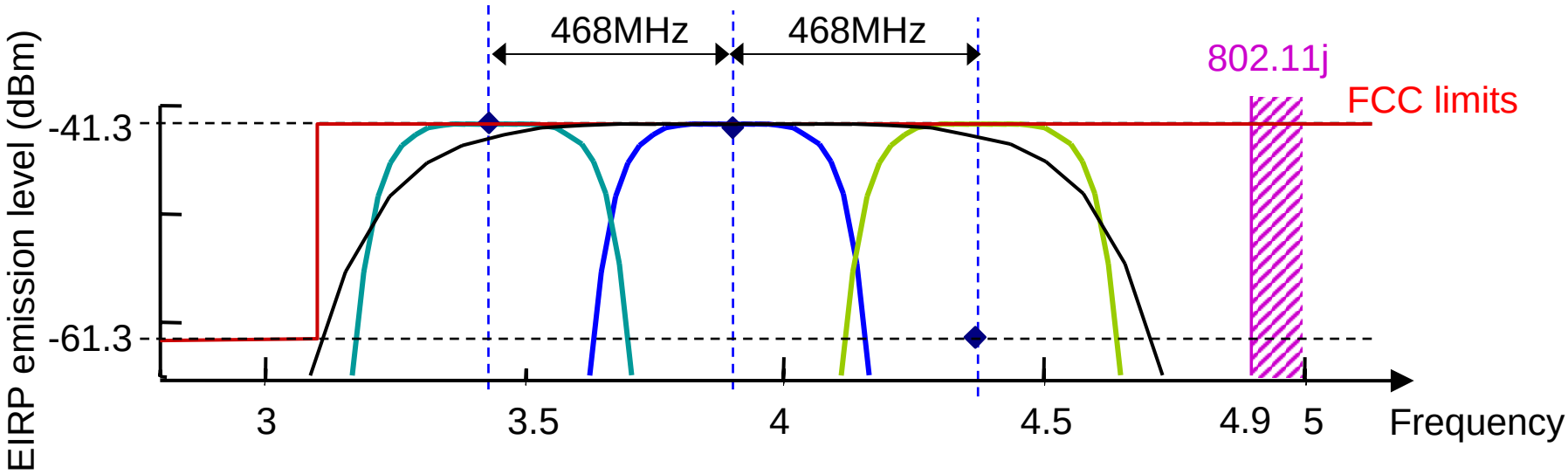


Insight of Frequency Plan (I)

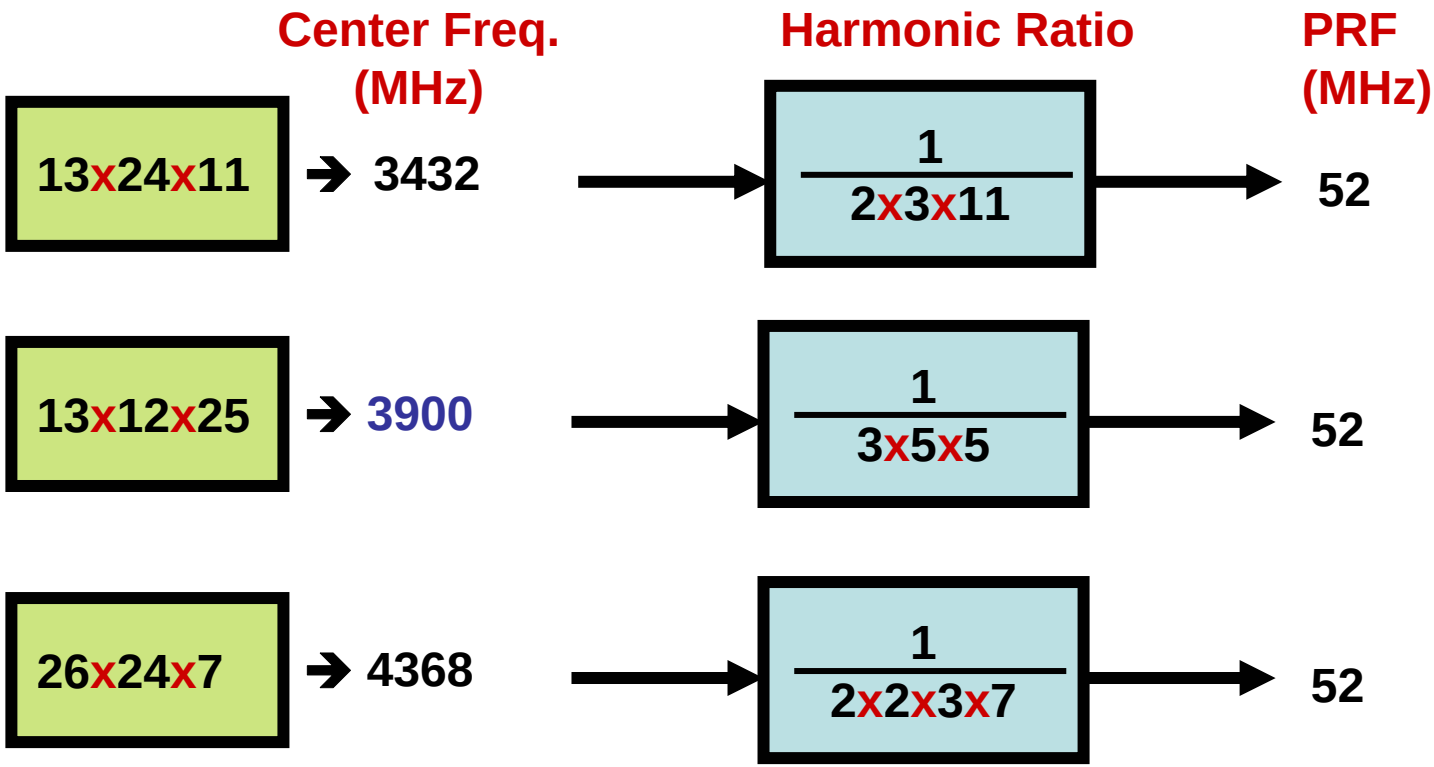
- PRF
  - All center frequencies are integer products of PRF (26MHz and 52 MHz).
- Crystal frequency
  - All center frequencies are integer product of 24 MHz (12MHz) and 26 MHz (13MHz).
- Bandwidth
  - No spectrum overlap between neighbor sub-bands. However sharp cut-off filter is required at 4.9 GHz.
  - 4.056GHz is slightly beyond 4.05GHz given in baseline.

Frequency Plan (II)

Band No.	Bandwidth (MHz)	Low Freq. (MHz)	Center Freq. (MHz)	High Freq. (MHz)
1	>=500	3182	3432	3682
2 (mandatory)	>=500	3650	3900	4150
3	>=500	4118	4368	4618
4	>=1500	3150	3900	4650



PRF Flexibility (II)



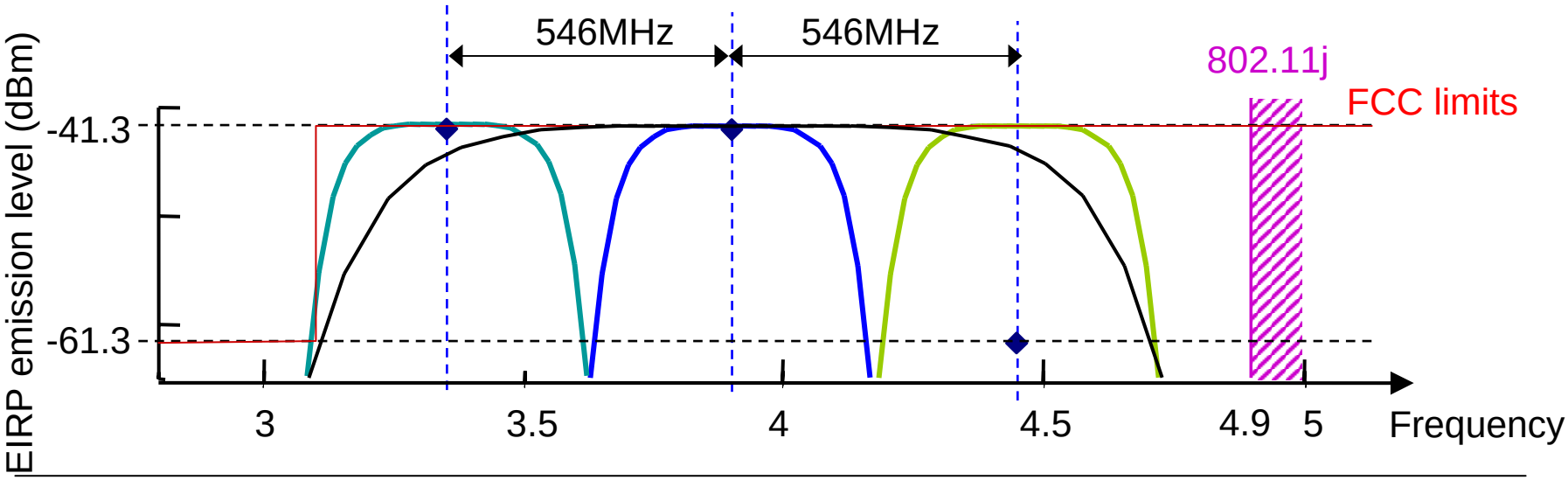
Prime factors: 2, 3, 5, 7, 11

Insight of Frequency Plan (II)

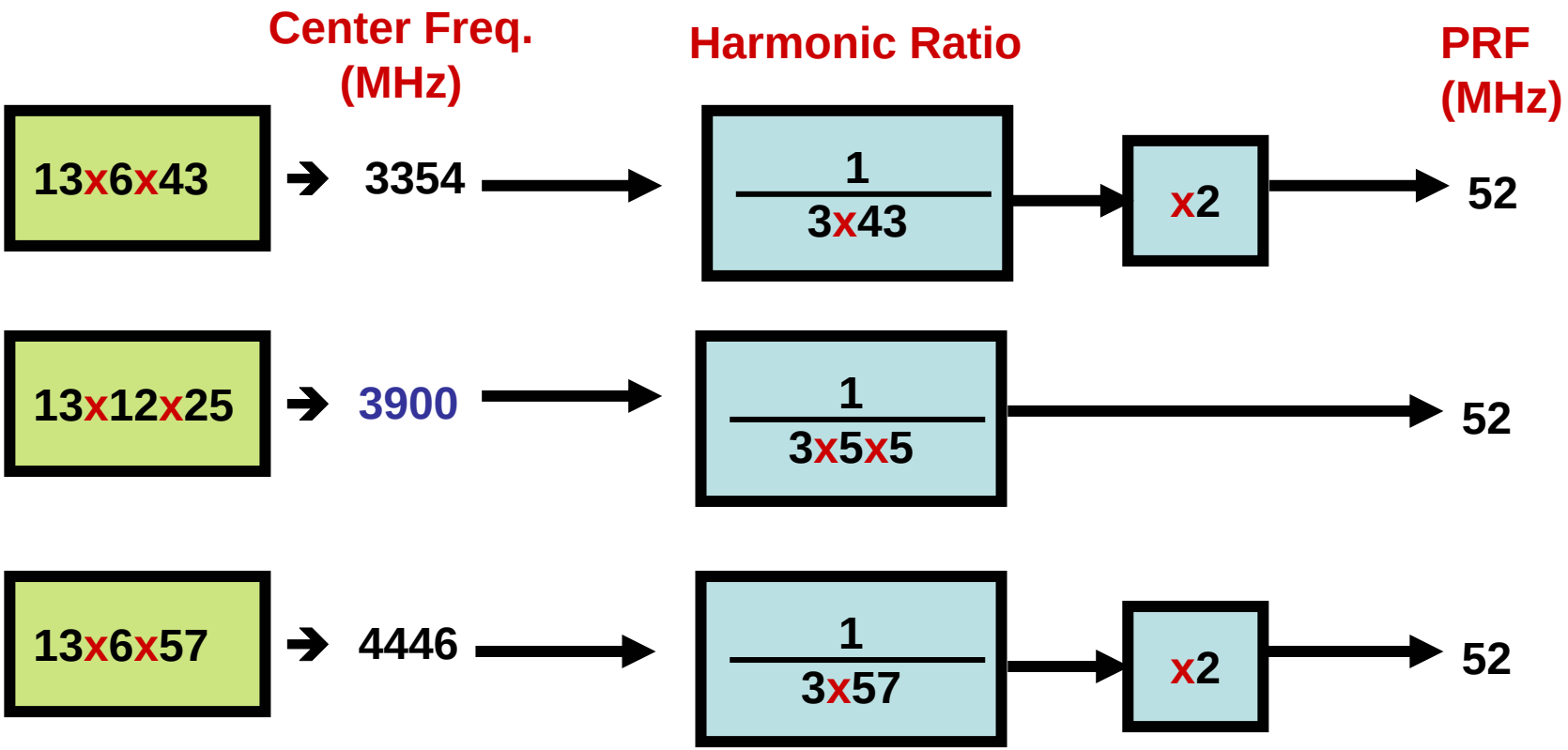
- PRF
  - All center frequencies are integer products of PRF (26MHz and 52 MHz).
- Crystal frequency
  - The mandatory center frequency is an integer product of 12MHz, and 26MHz (13MHz).
  - For 24MHz, an additional division by 2 is needed.
  - The other center frequencies are integer product of 24MHz (12MHz) and 26 (13MHz) MHz.
- Bandwidth
  - No need for sharp cut-off filters at 3.1GHz or 4.9GHz. However, spectrum overlap occurs between neighbor sub-bands.

Frequency Plan (III)

Band No.	Bandwidth (MHz)	Low Freq. (MHz)	Center Freq. (MHz)	High Freq. (MHz)
1	>=500	3104	3354	3604
2 (mandatory)	>=500	3650	3900	4150
3	>=500	4196	4446	4696
4	>=1500	3150	3900	4650



PRF Flexibility (III)



Prime factors: 3, 5, 43, 57

Insight of Frequency Plan (III)

- PRF
  - Mandatory center frequency is an integer product of PRF (26MHz and 52 MHz).
  - Optional center frequencies 2 and 3 are integer products of PRF of 26MHz.
  - An additional multiplication by 2 is needed to generate 52 MHz PRF for optional center frequencies 2 and 3.
- Crystal frequency
  - All center frequencies are integer products of 13MHz, and 26MHz.
  - For 24MHz, an additional division by 2 is needed for mandatory center frequency.
  - For 24MHz, an additional division by 4 is needed for optional center frequencies 2 and 3.
- Bandwidth
  - No spectrum overlap between neighbor sub-bands. However sharp cut-off filter is required at 3.1 GHz.

Which One Is the Favored

Frequency plan (III) serves our purpose better because

- At the mandatory center frequency
  - Integer product of PRF is satisfied for both 26MHz and 52MHz.
  - Only an additional division by 2 is needed for 24MHz crystal to satisfy the condition of integer product condition.

- At the optional center frequencies,
  - Integer products of 26MHz is satisfied. Only an additional multiplication with 2 is needed for 52MHz PRF.
  - Only an additional division by 4 is needed for 24MHz crystal to satisfy the condition of integer product condition.

- Division by 2 or 4, multiplication with 2 can be done with simple circuits.

Which One Is the Favored (continued)

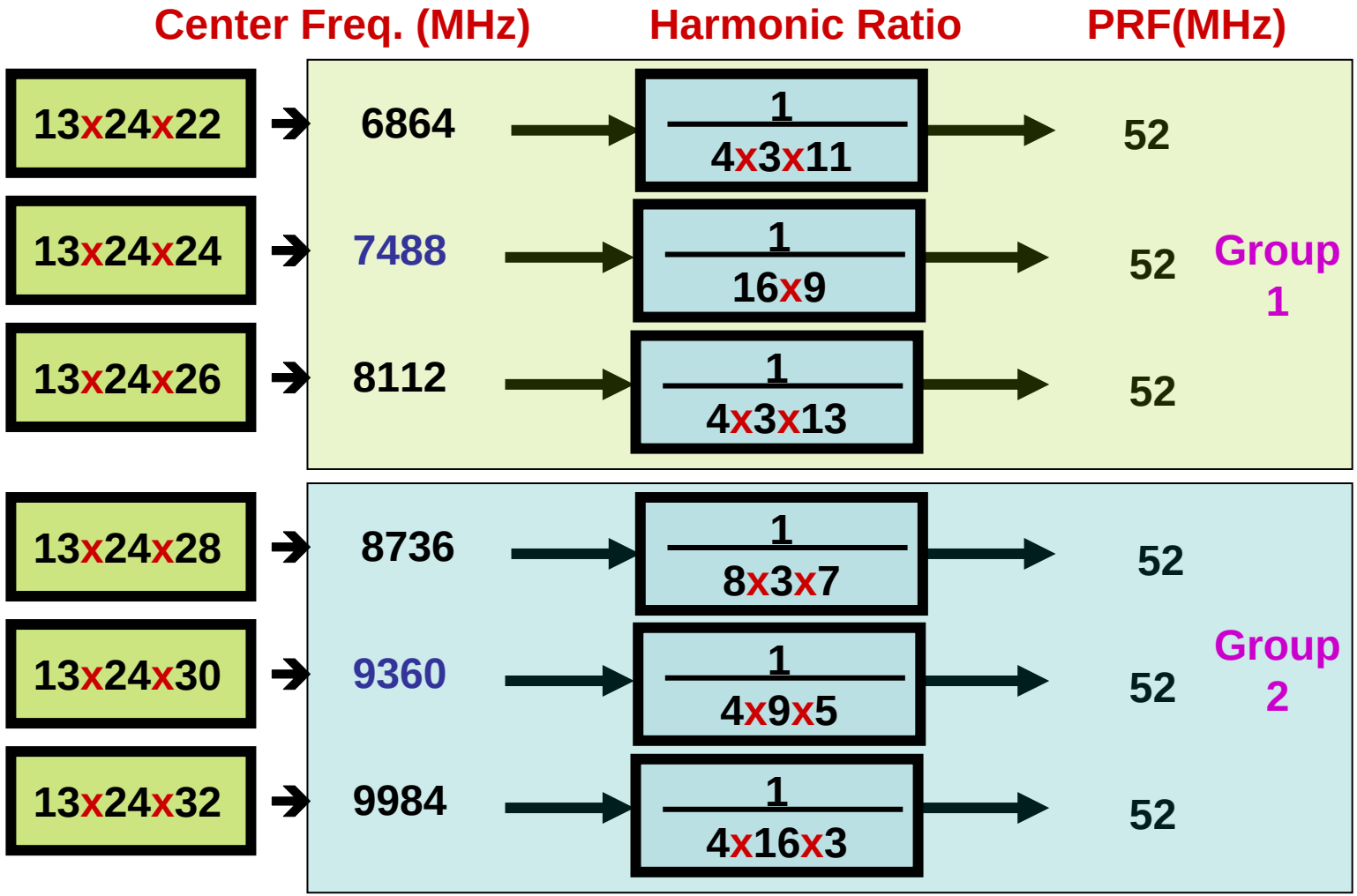
- Trade-off exists among different frequency plans. Plan (III) needs a sharp cut-off filter at 3.1 GHz. This can be mitigated if we allow a little spectrum overlap between the lower two subbands.

- When looking at the harmonic ratios, plan (III) is not a good choice. A possible “best” frequency plan may be resulted from the combinations of plan (II) and plan (III) by sticking to the requirements from applications.

Frequency Plan for Higher Band

Group No.	Band No.	Bandwidth (MHz)	Low Freq. (MHz)	Center Freq. (MHz)	High Freq. (MHz)
1	1	>=500	6614	6864	7114
	2	>=500	7238	7488	7738
	3	>=500	7862	8112	8362
	4	>=1500	6738	7488	8238
2	1	>=500	8486	8736	8986
	2	>=500	9110	9360	9610
	3	>=500	9734	9984	10234
	4	>=1500	8610	9360	10110

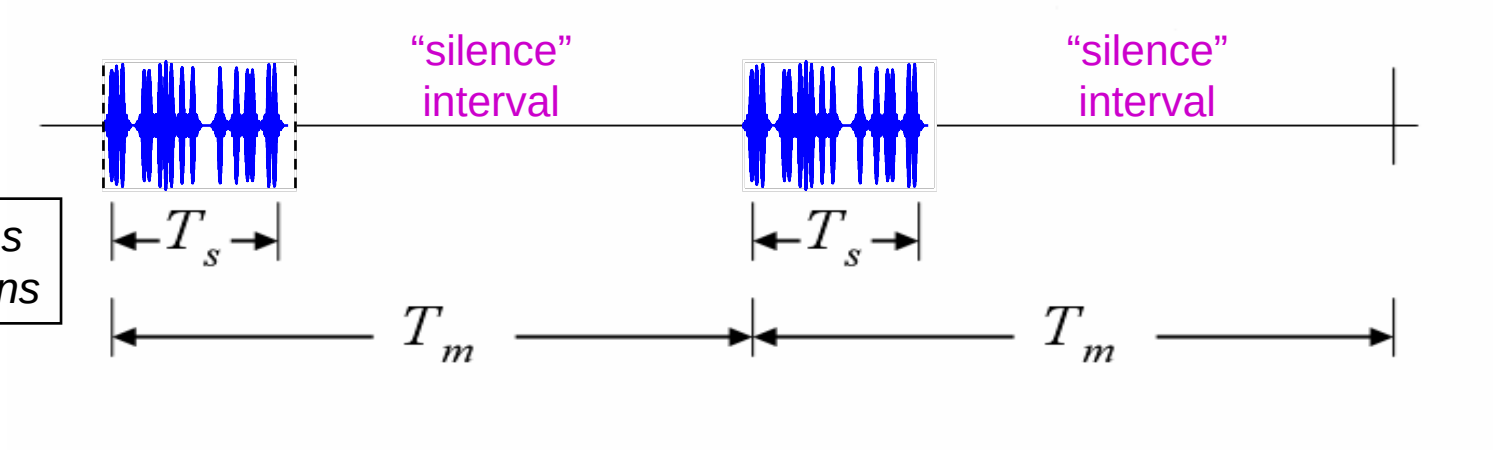
PRF Flexibility For Higher Band



Insight of Higher Frequency Plan

- PRF
  - All center frequencies are integer products of PRF (26MHz and 52 MHz).
- Crystal frequency
  - All center frequencies are integer product of 24 MHz (12MHz) and 26 (13MHz) MHz.
- Bandwidth
  - No spectrum overlap between neighbor sub-bands.

Example of Signal Structures



T_s = 109 ns
T_m = ~218 ns

Examples of Data Rates

# Chip / symbol (Code length)	**24-chip sequence + 24-chip "zero" padding (silence)**
"Chip rate" inside burst	**221 MHz (= F_{center} / 6)**
Channel coding	**(24,12) extended Golay code, r=1/2**
Symbol Rate	**Same as Pulse burst frequency above**
Mandatory bit rate	**1/2 x 2.3 MSymbols/s = 1.15 Mbps**
Optional bit rates (others possible) **(For "coherent-only" higher rate modes, no zero padding is used so the symbol rate is $1/T_{m)}$**	**1/2 x 4.6 MSps = 2.3 Mbps (non-coherent)** **1/2 x 9.2 MSps = 2.3 Mbps (coherent)** **1/2 x 18.4 MSps = 4.6 Mbps (coherent)**
Lower bit rate scalability	**Symbol Repetition**
Modulation	**{+1,-1} bipolar and PPM/OOK of ternary pulse train**
Multiple access for piconets	**CDM (fixed code) + FDM (fixed band)**

Preamble Structure Proposal

- **Three structures with three function fields for different doings**

-for communication of continuously sending data under stable radio channels

⇨same as 15.4 PHY preamble

-for communication being able to do radio channel adaptation

⇨ adding channel estimation filed

-for simultaneous communication and ranging

⇨ adding ranging filed