Code Generators Used by the Galileo L1 Signal

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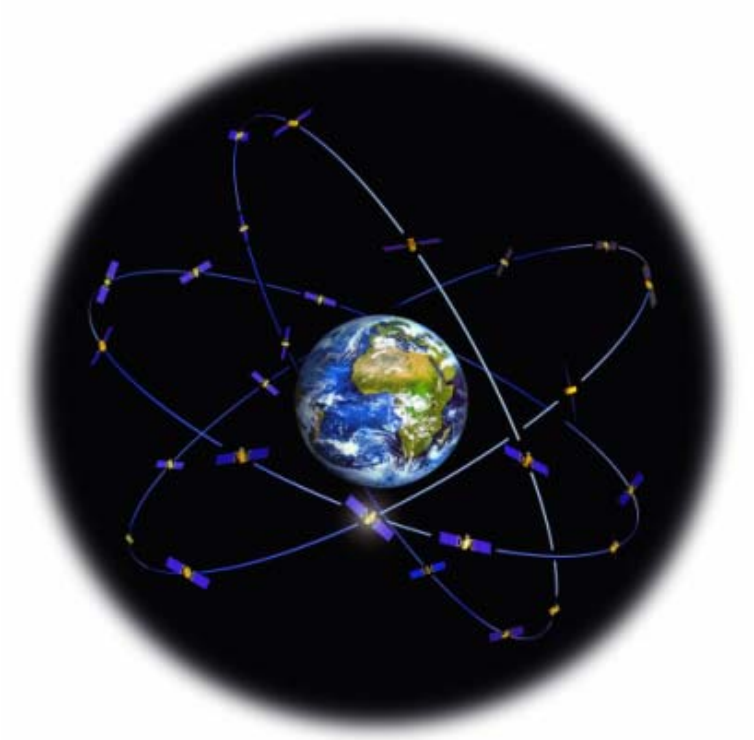
April 25, 2006

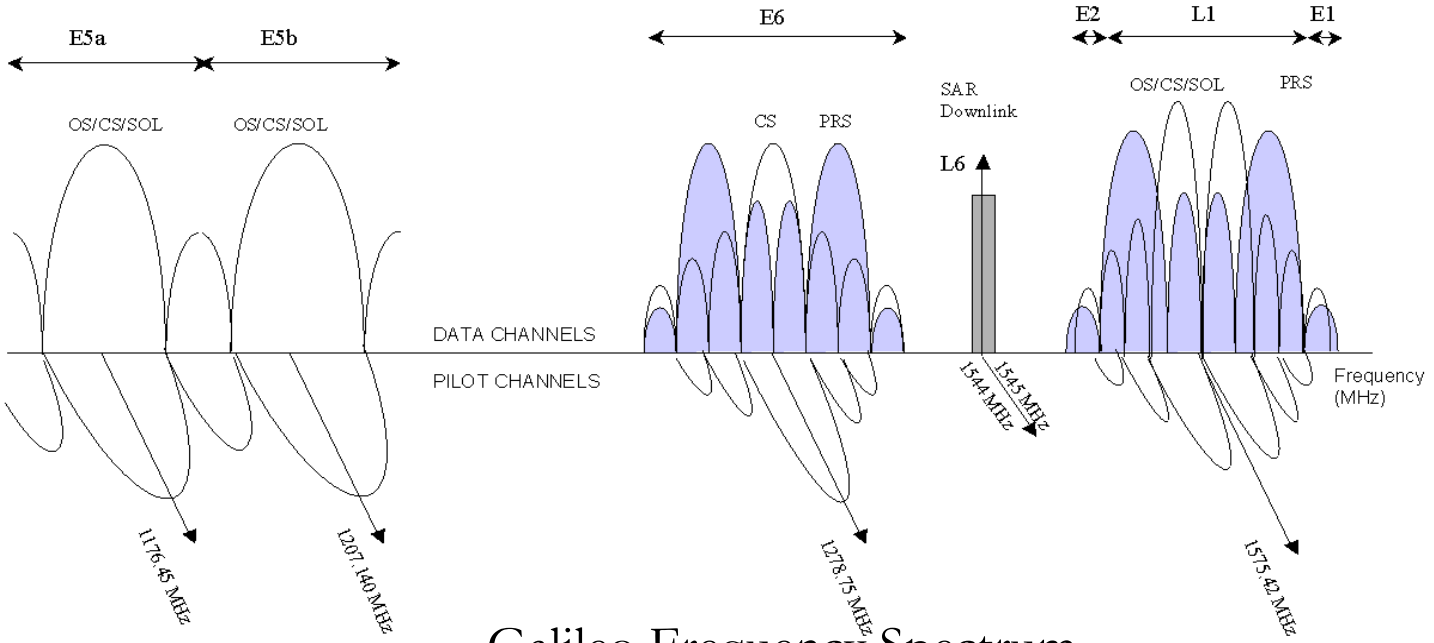
Galileo System



- Global Navigation Satellite System built by European Union
  - Operational 2008
  - The first Galileo test satellite – GIOVE-A was launched on Dec.28, 2005
  - First navigation signals were transmitted by GIOVE-A on Jan.12, 2006
- Interoperable with GPS
- 30 satellites in three Medium Earth Orbit MEO planes at 23,616km above the earth
  - 9 satellite + 1 spare per plane
  - The inclination of the orbits was chosen to ensure good coverage of polar latitudes, which are poorly served by the US GPS system
- One revolution 14 hours 4 min

Why Study Galileo?

- Galileo provides additional 30 satellites to the US GPS system
  - More accuracy and integrity
- Galileo L1 band overlaps with GPS L1 band
  - Can use the same antenna for the integrated Galileo/GPS receivers

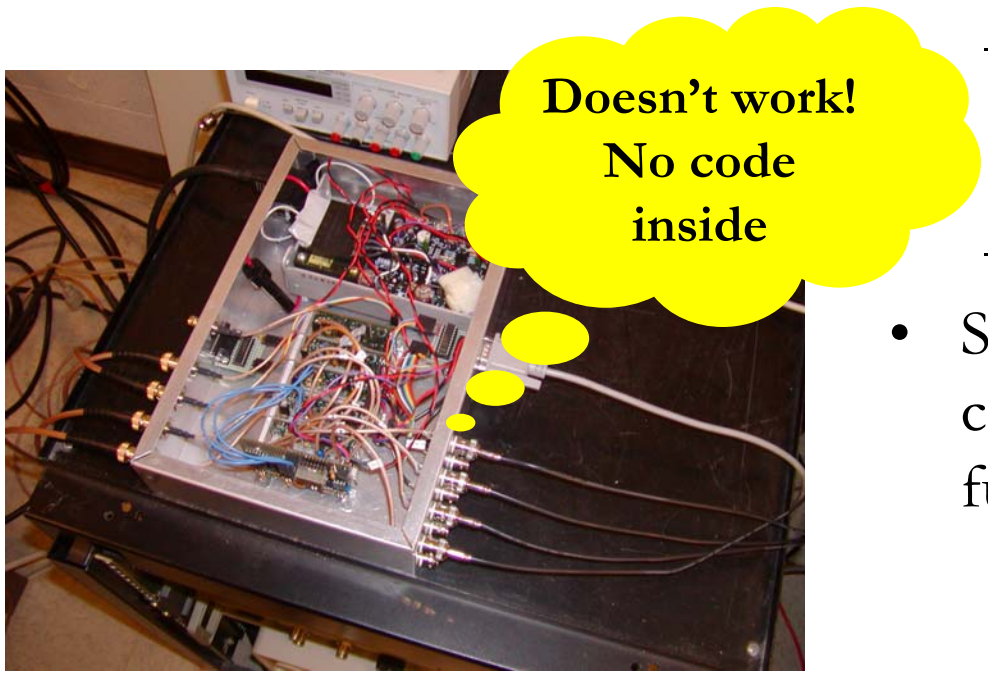


Galileo Frequency Spectrum

Illustrations from ESA

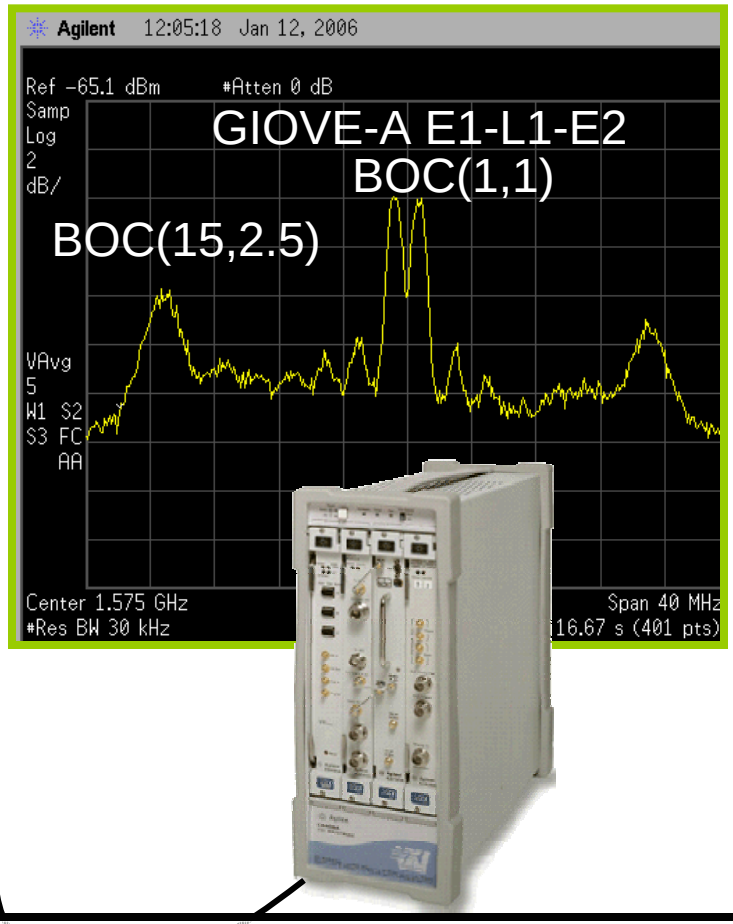
Why Seek the Galileo Codes?

- A Fancy Galileo Receiver



- It doesn't work
  - PRN Codes, and code generators are Unknown, although claimed to be made public
  - Commercial issues
- Studying the Galileo codes also contributes to the design of future GPS codes.

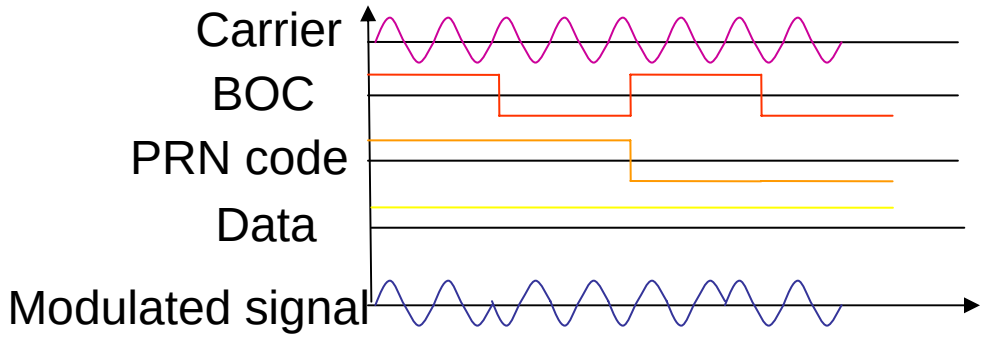
Data Collection

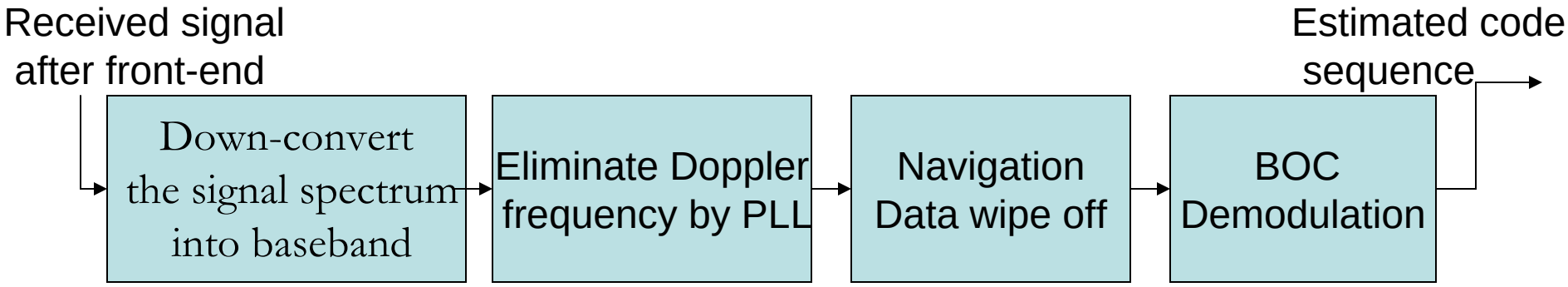


- Dish allowed us to see Galileo GIOVE-A signal when transmission was initialized
- Code not necessary for data capture
- Vector Signal Analyzer used to capture data from transmission

Estimate Individual Code Sequences

- Modulated signal is the product of carrier, BOC code, PRN code, and data

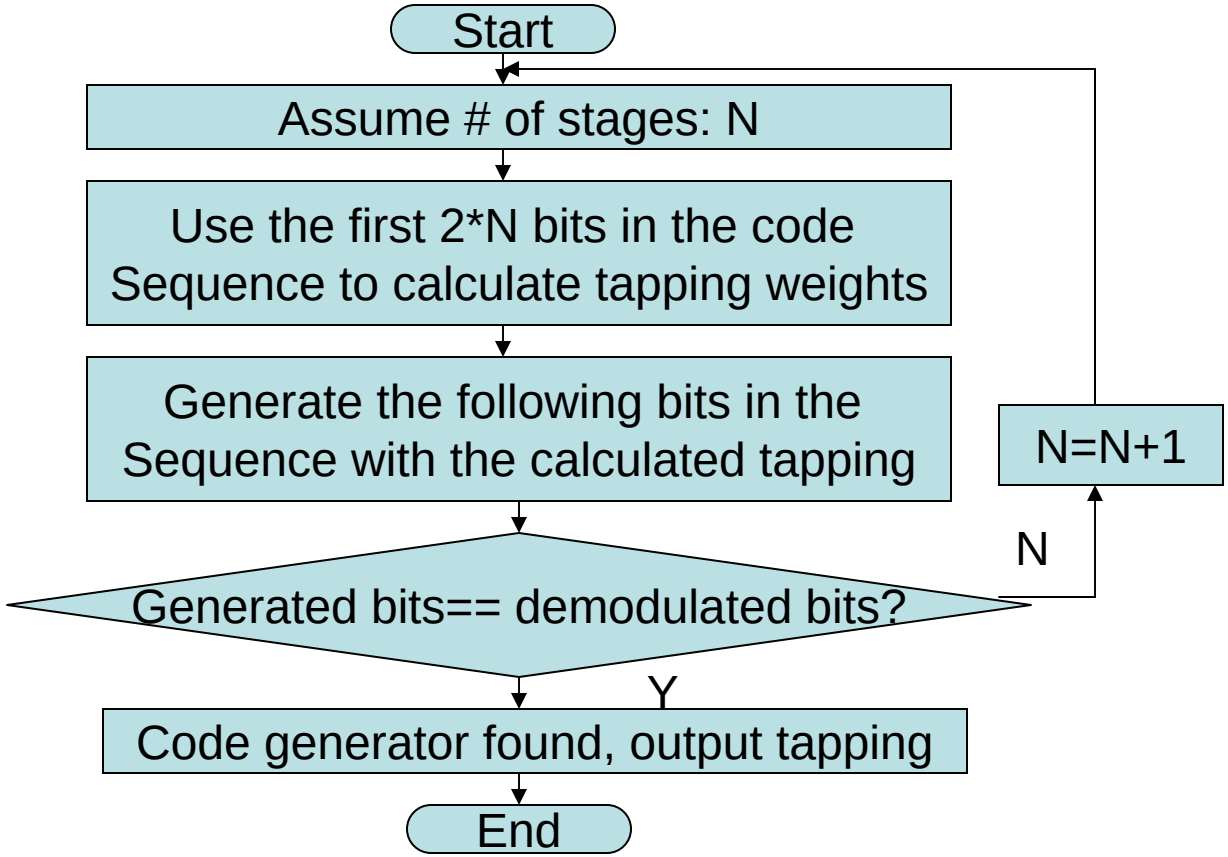




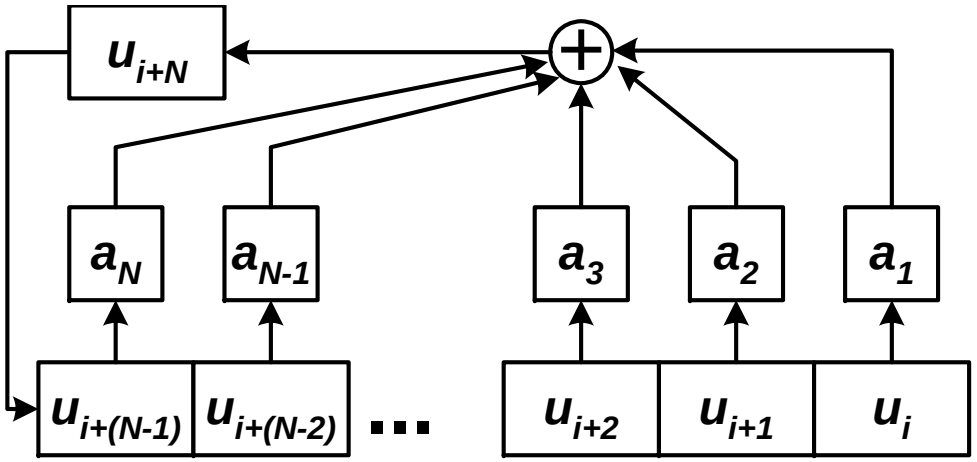
Estimated code sequence: Code1, 4092 bits long
Code2, 8184 bits long

Calculate Code Generator Stages

- Start with linear codes
  - Searching all 2^4092 codes for good autocorrelation and then sorting and ranking them may require too much computation
- Calculate generator tapping weights



Estimating Taps on LSFR



- We have u_i, i = 1, …, 2*N, …
- Determine which taps are on or off (a_n = 0 or 1)
- For every set $u_i,\ldots,u_{i+N}$, the relationship is:

$$u_{i+N} = a_N * u_{i+(N-1)} \oplus a_{N-1} * u_{i+(N-2)} \oplus \cdots \oplus a_2 * u_{i+1} \oplus a_1 * u_i$$

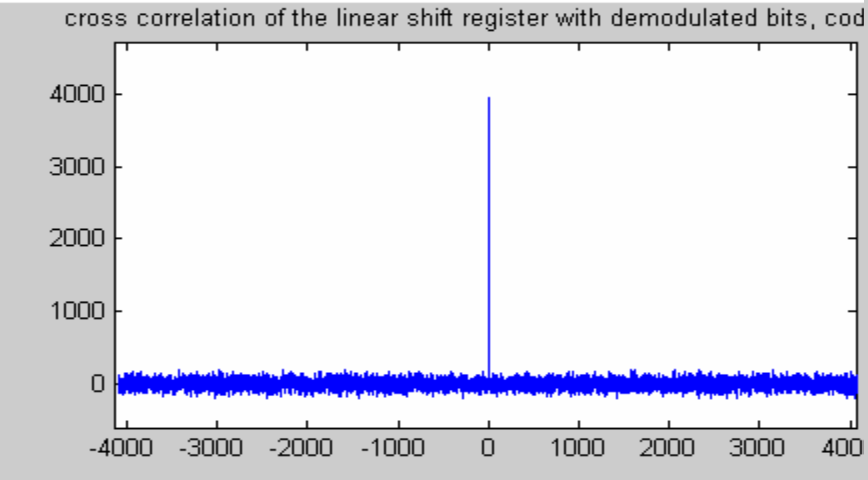
- The relationship for N distinct values of i yields N equations
  - Can solve for a_n
  - Used first 2*N bits for solution, remaining bits can be used to verify

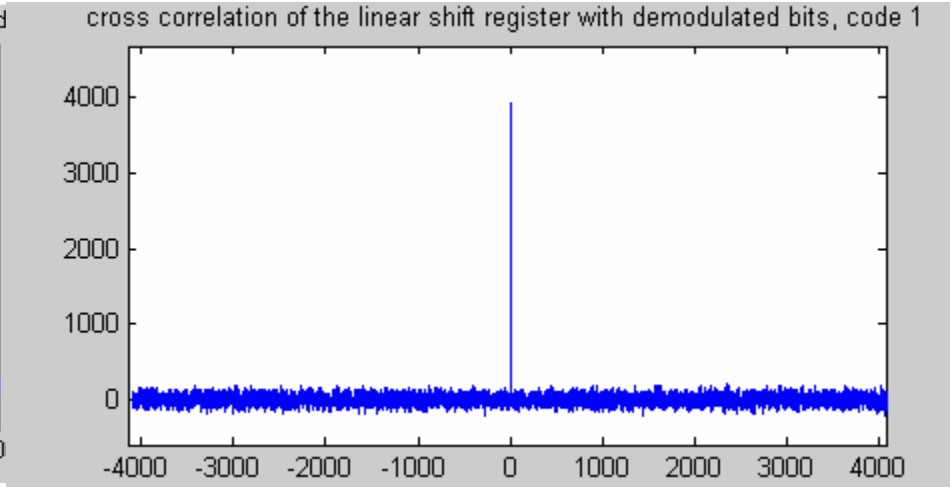
Obtain Code Generator Polynomials

- Obtain code generator polynomial
  - Both codes are linear codes
  - Each code is generated by a 26 order polynomial
  - Factorize obtained code generator polynomials
  - The code sequence can be generated by module2 adding maximal length sequences of the factor polynomials
- Code 1 (Gold code)
  - Poly1_code1 = $X^{13}+X^{10}+X^{9}+X^{7}+X^{5}+X^{4}+1$
  - Poly2_code1 = $X^{13}+X^{12}+X^{8}+X^{7}+X^{6}+X^{5}+1$
- Code 2 (Gold code)
  - Poly1_code2 = $X^{13}+X^{10}+X^{9}+X^{7}+X^{5}+X^{4}+1$
  - Poly2_code2 = $X^{13}+X^{4}+X^{3}+X+1$

Linear Shift Register Vs. Demodulated codes

- Cross correlation – 26dB processing gain





- Discrepancies
  - Both generated codes have ~2% of discrepancies from the demodulated code.
  - Only 2% energy loss for Galileo receivers, minor effect
  - The disagreement may come from receiving signal errors

Summary & Future Work

- Galileo Giove-A L1 signal has two Spreading Codes
- Both codes are truncated gold codes. Each one is generated by two 13-stage shift registers
- Both codes provide 26dB processing gain
- Next step: Data collected from Stanford Big Dish