F5—A Steganographic Algorithm

High Capacity Despite Better Steganalysis

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Outline

Benefits of F5

Properties of existing tools

From Jsteg to F5

How secure is F5?

My challenge to you

Benefits of F5

- High steganographic capacity
- High efficiency via matrix encoding
- Prevents visual attacks
- Resistant to statistical attacks (chi square)
- Uses JPEG as carrier (common in e-mails)
- Source code publicly available

Existing Steganographic Tools

- Their properties:
  - High capacity
  - Weak against visual and statistical attacks
  - Remove significant image content
  - Overwrite LSBs
- Way out?
  - Dilute the changes ➨ less capacity
  - Different embedding operation
  - Different carrier medium

From Jsteg to F5

- Jsteg
  - Easily detected by statistical attacks
  - JPEG compression
  - Embedding function of Jsteg
- F4 (improved embedding operation)
- F5 (advanced efficiency)
  - Permutative straddling
  - Matrix encoding

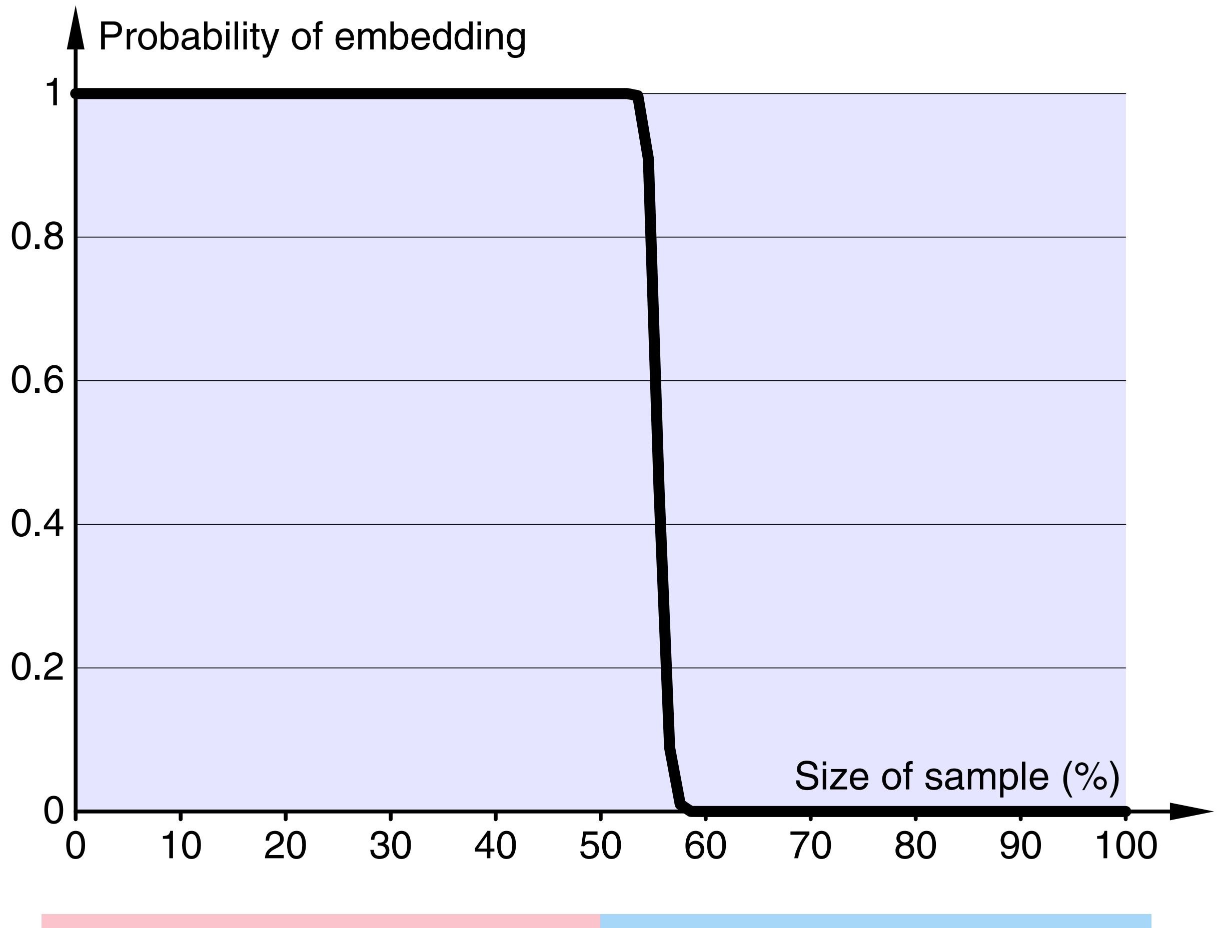
Statistical Attack on Jsteg

Jsteg is safely detected by statistical attack.

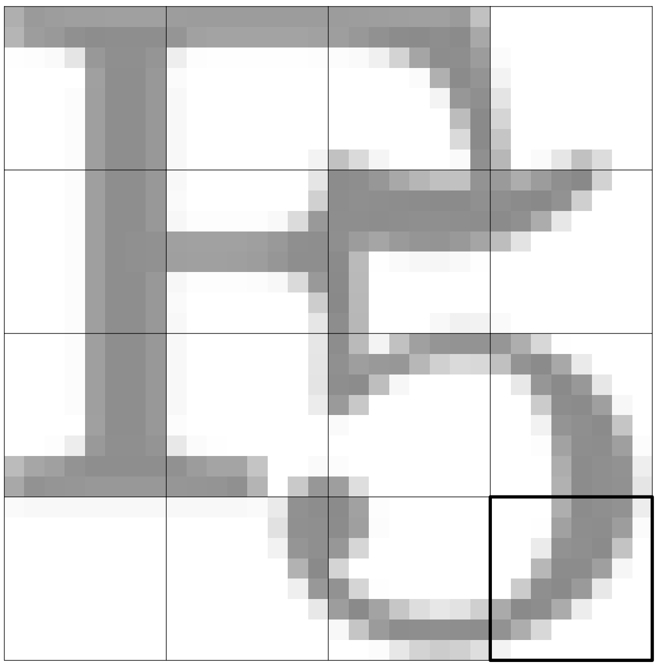
Message

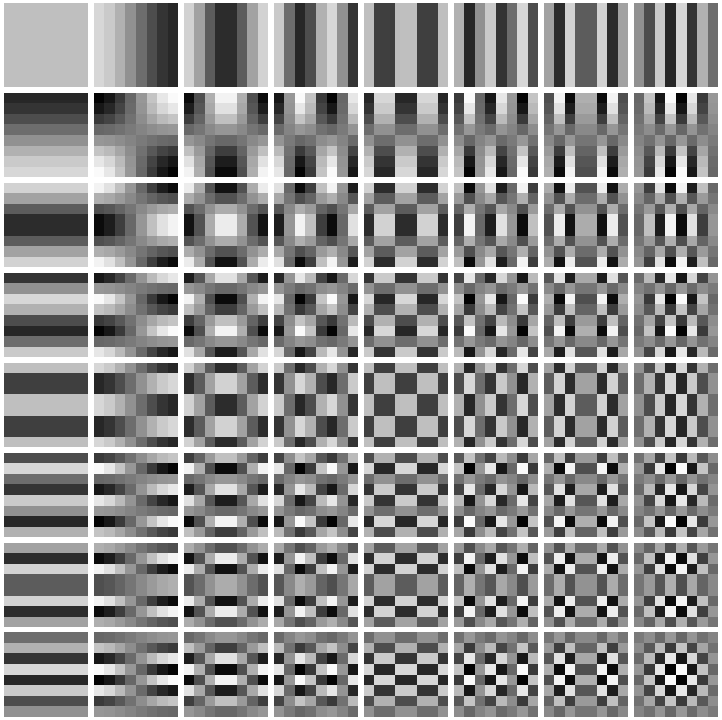
```
M/uogOCS
n21OTx0c
...
```

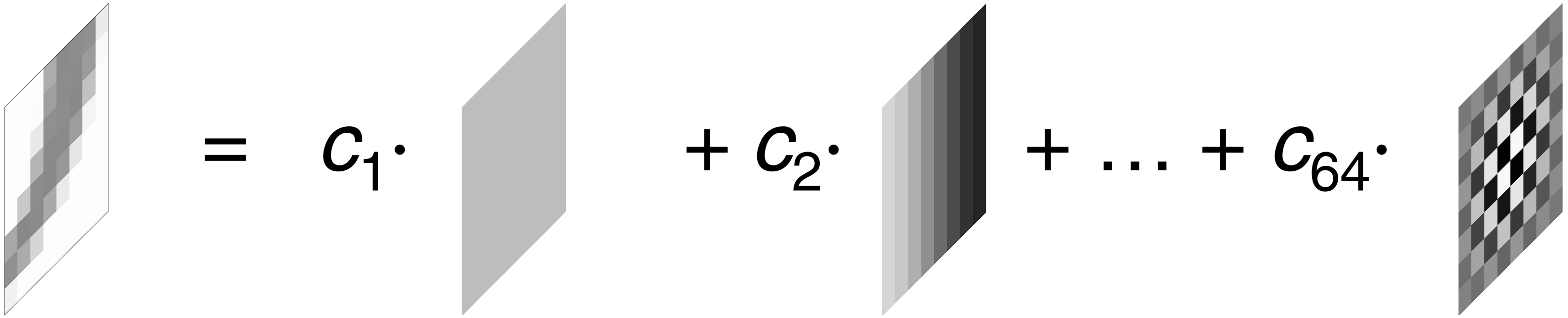
Steganogram



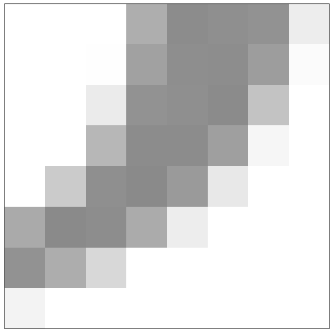
JPEG Coefficients





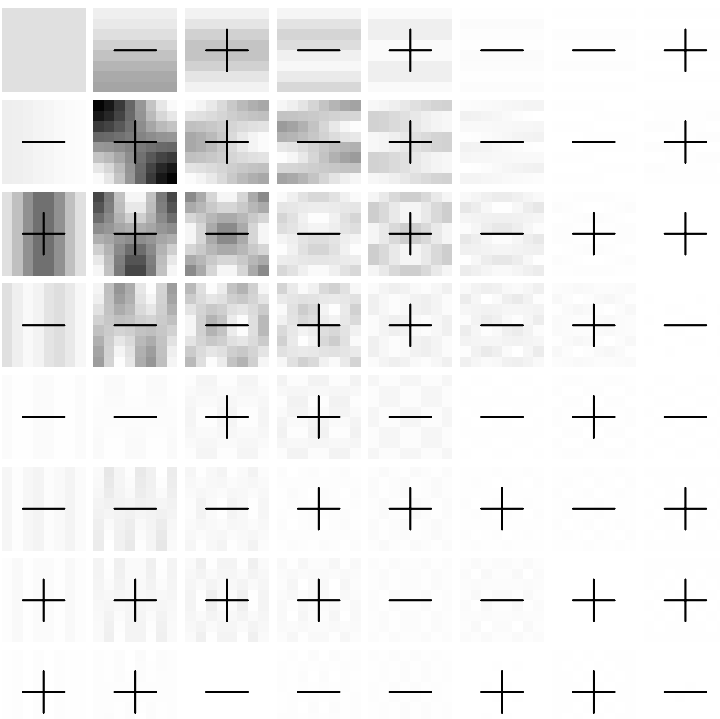


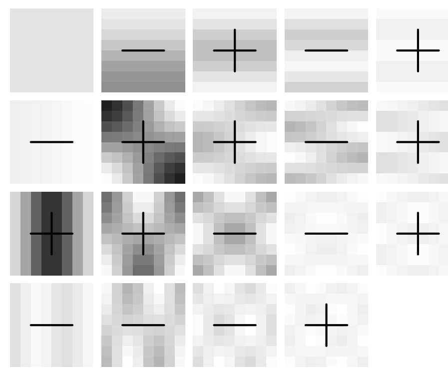
Discrete Cosine Transformation

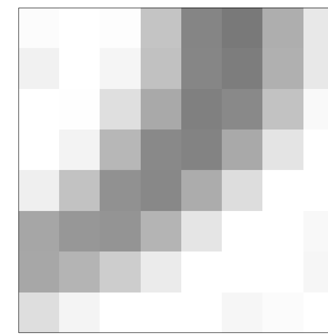


64 brightness values

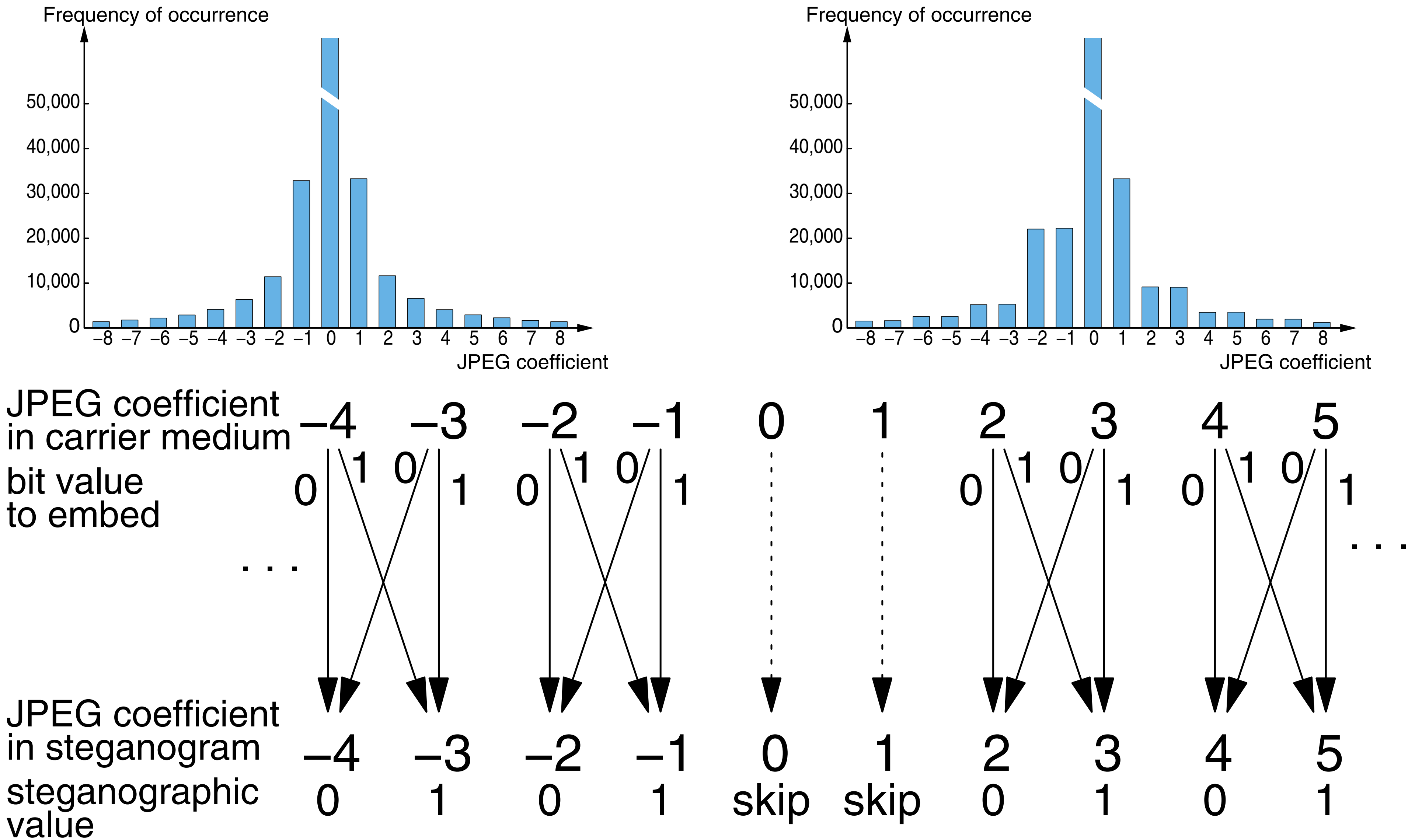
➧ 19 nonzero JPEG coefficients



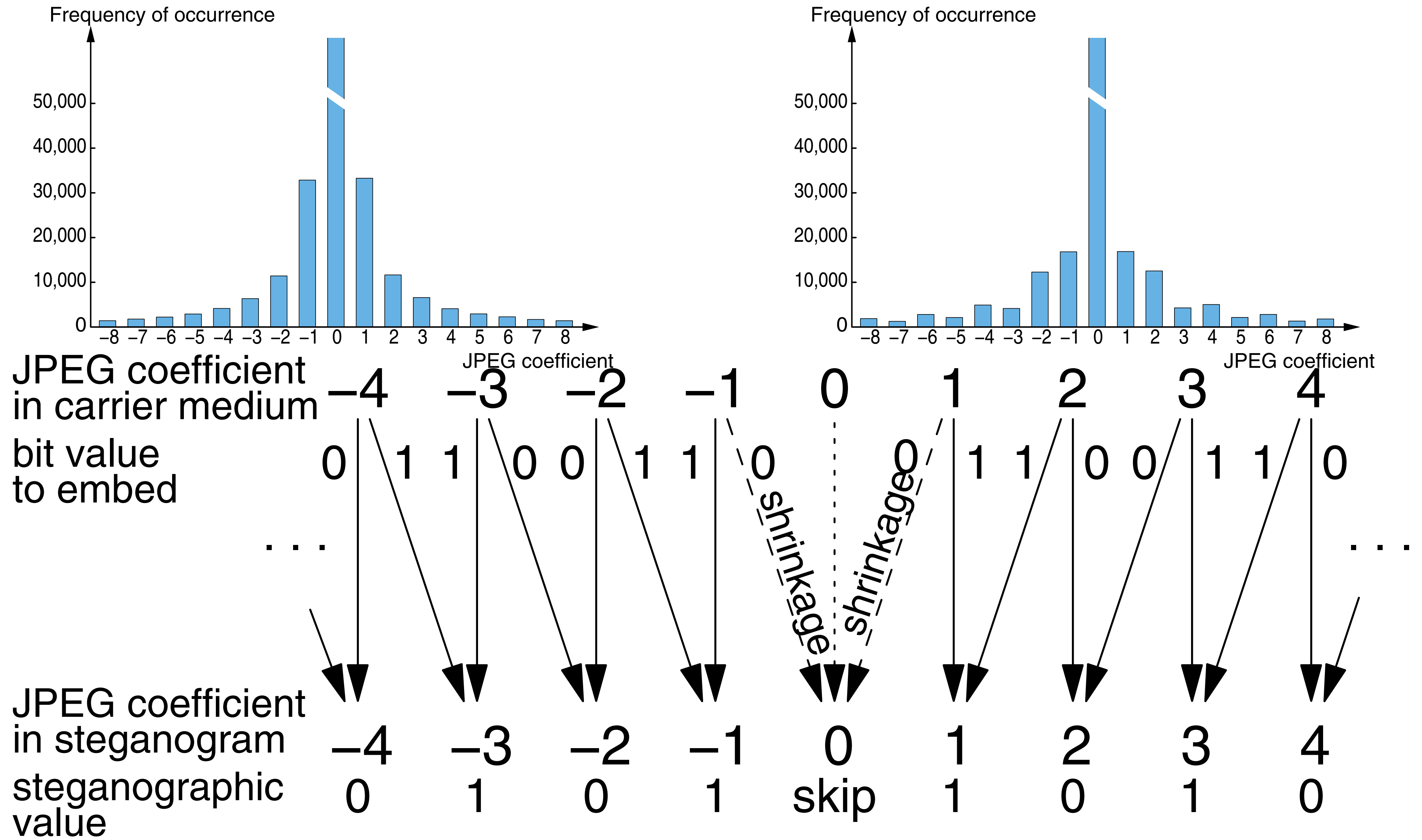




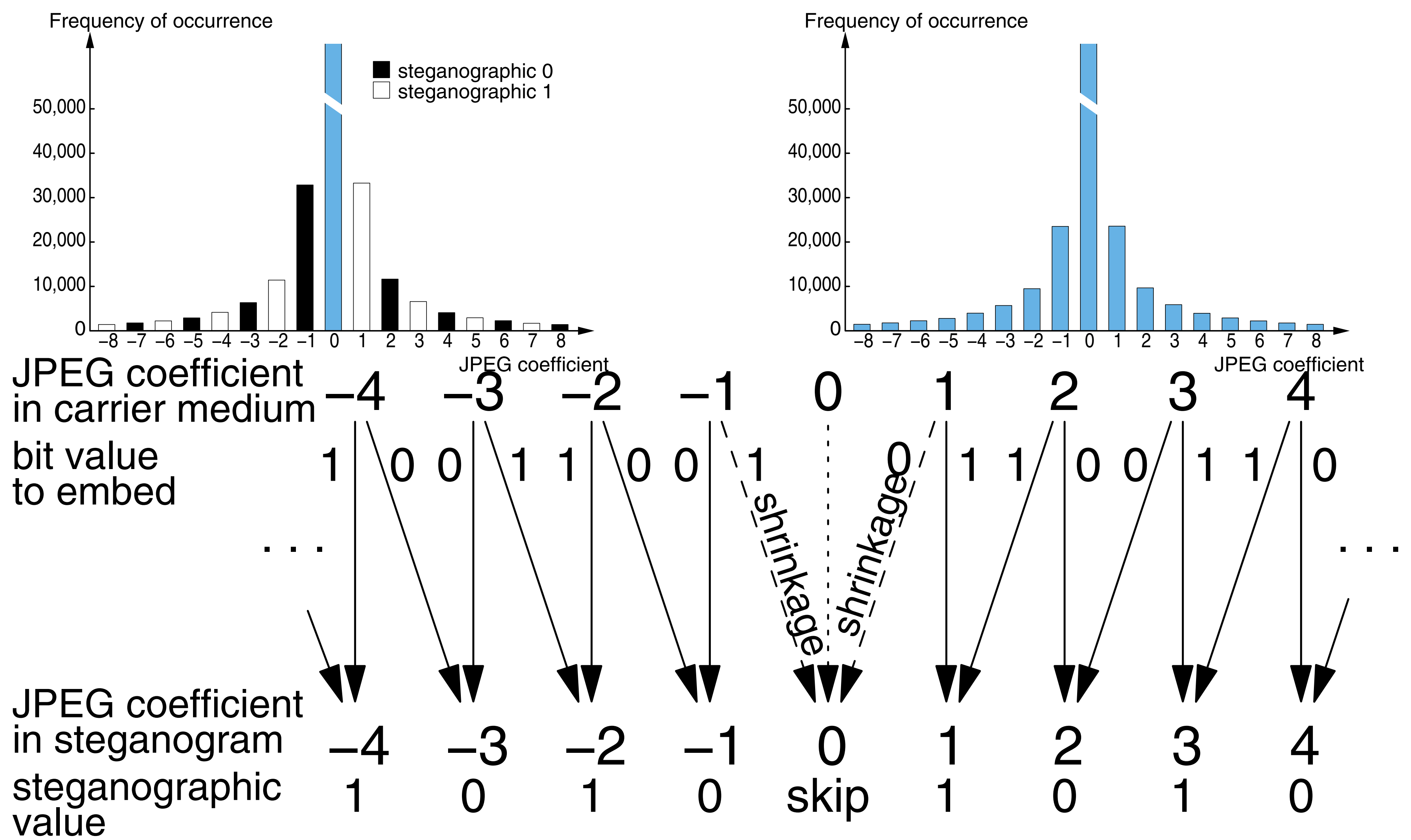
Algorithm Jsteg



Algorithm F3

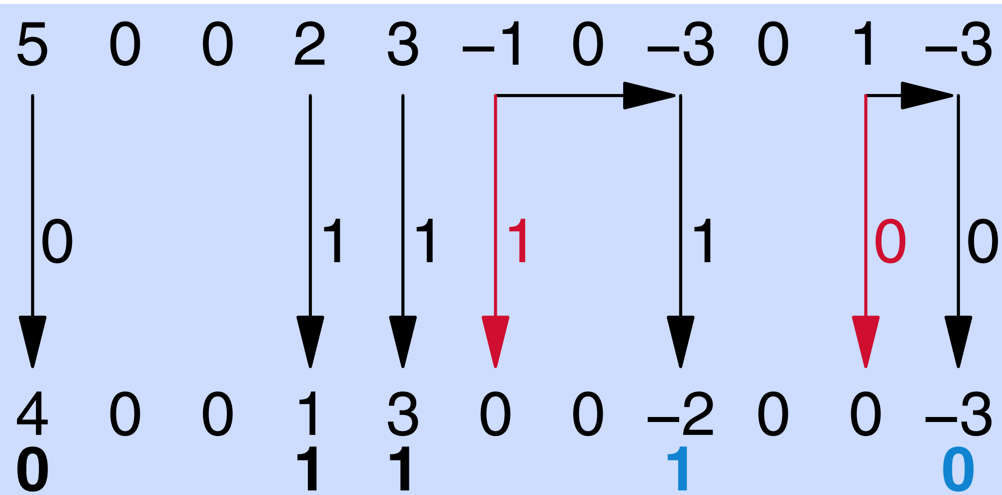


Algorithm F4

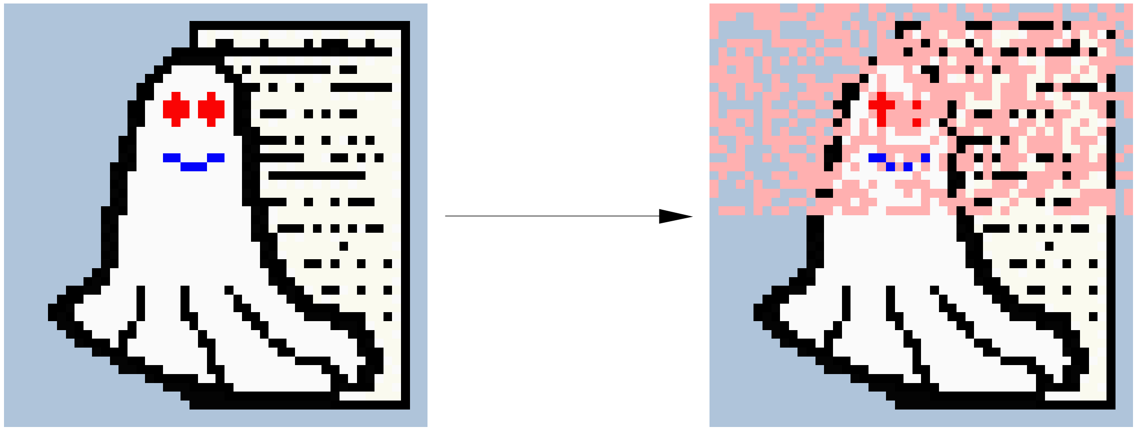


How F4 Embeds “01110”

- Steganographic interpretation
  - Positive coefficients: LSB
  - Negative coefficients: inverted LSB
- Skip 0, adjust coefficients to message bit
  - Decrement positive coefficients
  - Increment negative coefficients
  - Repeat if shrinkage occurs

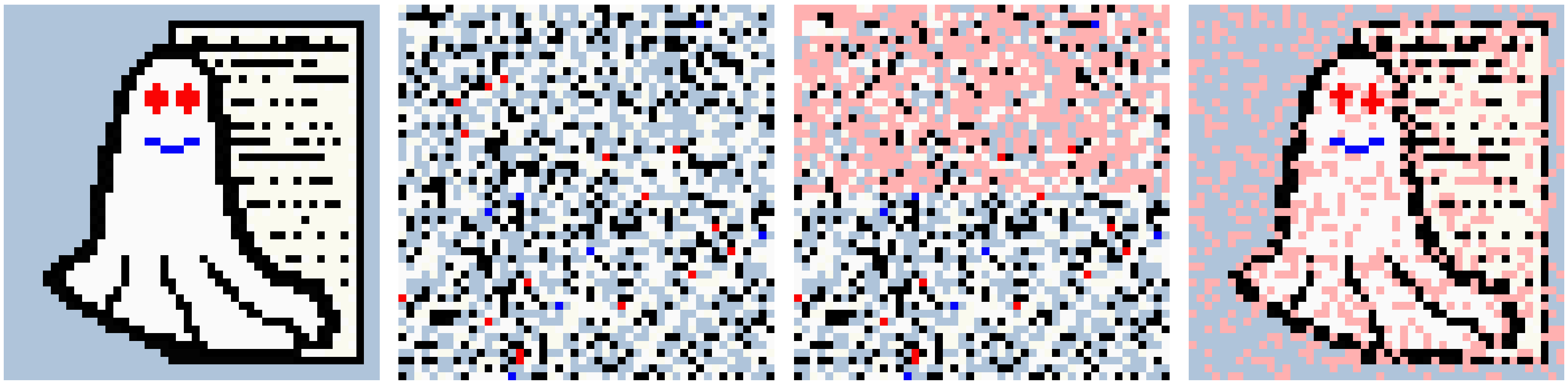


Continuous Embedding



- Changes reside packed at the start of the file (marked with pink)
- Attacks profit from the high change density

Algorithm F5: Straddling



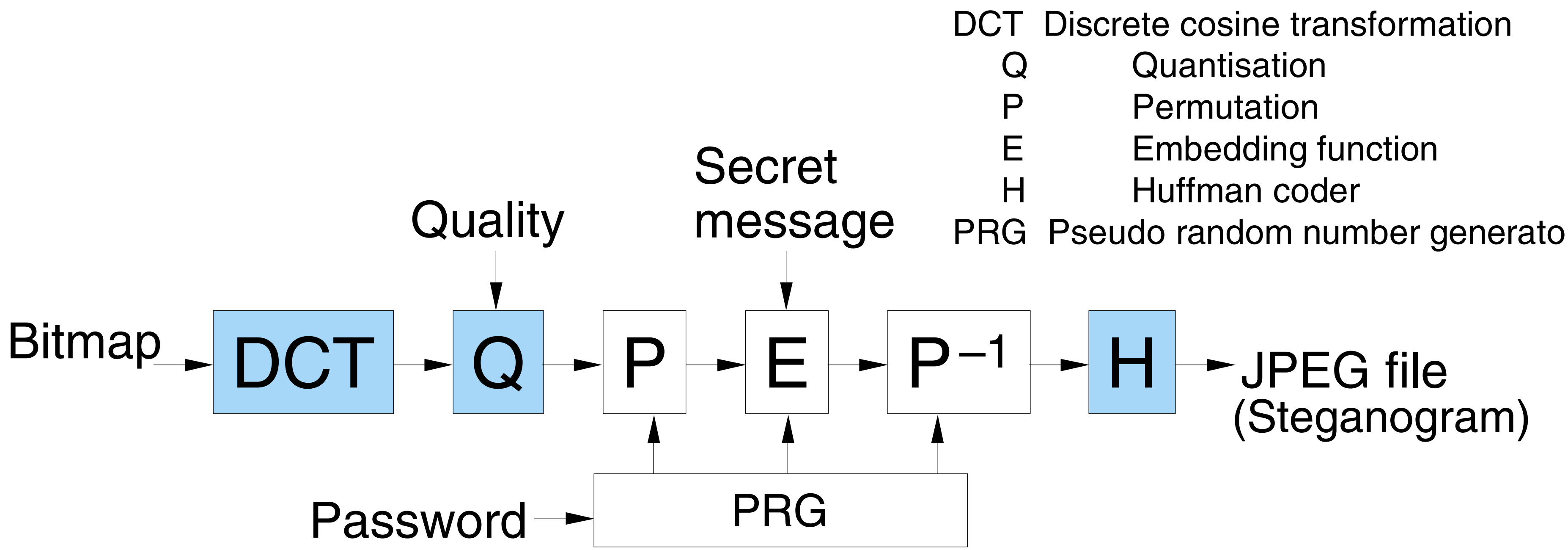
- Permutation equalises the change density
- Scatters the message more uniformly than
  - Key-driven distance schemes
  - Parity block schemes
- Independent of message length

F5 Uses Matrix Encoding

Embed k bits by changing one of $n = 2^k - 1$ places:

k	n	change density	embedding rate	embedding efficiency
1	1	50 %	100 %	2
2	3	25 %	66.7 %	2.7
3	7	12.5 %	42.9 %	3.4
4	15	6.25 %	26.7 %	4.3
k	n			$> k$

Implementation of F5

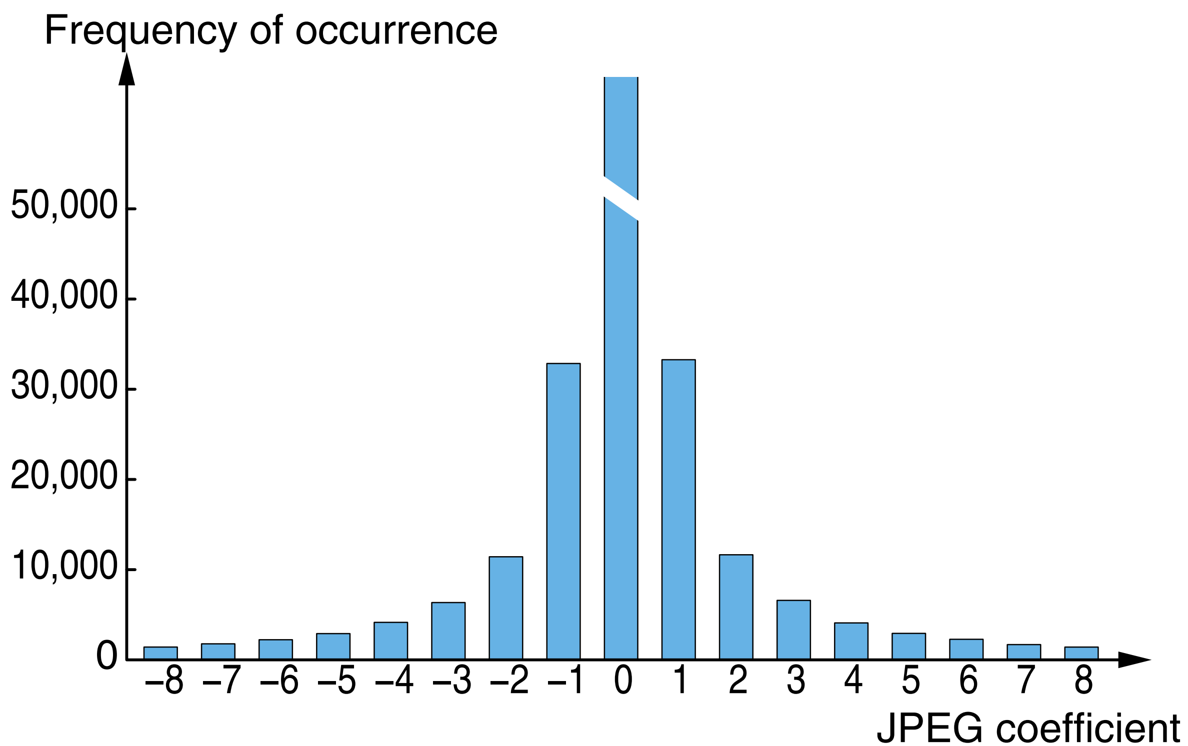


- Password-driven permutation
- Pseudo one time pad for uniformly distributed message
- Matrix encoding with minimal embedding rate
- Core embedding operation like F4

Capacity and Efficiency of F5

- Large carrier medium *expo.bmp (1526 KB)*
- Clean JPEG (80 % Quality) *expo80.jpg (127 KB)*
- Maximum embedded *maxisteg.jpg (113 KB)*
  - Size: 16 KB, i. e. 13 %
  - Efficiency: 1.5 bits per change (incl. shrinkage)
- Short message embedded *ministeg.jpg (127 KB)*
  - Size: 0.2 KB
  - Efficiency: 3.7 bits per change (incl. shrinkage)
  - Without matrix encoding twice as much changes
- Clean JPEG (75 % Quality) *expo75.jpg (113 KB)*

Characteristic Properties



$$P(X=1) > P(X=2) > P(X=3) > P(X=4)$$

$$P(X=1)-P(X=2) > P(X=2)-P(X=3) > P(X=3)-P(X=4)$$

Conclusion

- High steganographic capacity still possible
- High efficiency (embed more bits per change)
- Resistant against statistical attack (chi square)
- Uses a common carrier medium (JPEG)
- Publicly available source code

Further Work

- High steganographic capacity (13 % of a JPEG)
  - stronger attacks possible?
- Finer gradation of embedding efficiency by (d_{max}, n, k) matrix encoding with $d_{max} > 1$
  - too complex (too slow)?

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