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Spreading Codes

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Abstract:

Spreading sequences are called Pseudo Noise sequences. These codes are periodic binary sequence having noise like waveform. Generally, noise is a random signal and cannot be predicted, i.e., no mathematical expression can exist for random signal. But Pseudo Noise signals are deterministic signals known to both transmitter and receiver. Even though PN sequences are random in nature, they are not completely random because they get replicated for every period and appear to have the statistical properties of sampled white noise, i.e., impulse autocorrelation function and zero cross correlation. Hence the name Pseudo Noise to spreading sequences. the appropriate type of spreading code has to be selected for the relevant situation or application. This choice of selection depends upon the autocorrelation and cross-correlation functions of the codes. Good autocorrelation property is used for an accurate determination of the propagation delay hence used in Radar or positioning systems and in Mobile communication systems for separating the different propagation paths to avoid intersymbol interference. orthogonality alone is not sufficient for scenarios where (i) the code signals are not transmitted synchronously (ii) high delay spread due to multipath propagation occurs. In that case cross-correlation has to be minimized. The codes giving the best compromise for the respective applications have to be selected because each of the known types of codes fulfils one requirement to a higher and the other to a lower degree. The objective of the paper is to Present complete picture of spreading codes.

1. Maximal Sequences:

1.1 No of shift registrars = 2

Tap Combinations = (1, 2)
Sequence for (1, 2) Taps is {1 1 0}

1.2 No of shift registrars = 3
Tap Combinations = (1, 3) (2, 3)
Sequence for (1, 3) Tap is {1 1 1 0 1 0 0}
Sequence for (2, 3) Tap is {1 1 1 0 0 1 0}

1.3 No of shift registrars = 4
Tap Combinations = (4, 1) (4, 2)
Sequence for (4, 1) Tap {1 1 1 1 0 1 0 1 1 0 0 1 0 0 0}
Sequence for (4, 2) Tap {1 1 1 1 0 1 0 1 1 0 0 1 0 0 0}

1.4 No of shift registrars = 5
Tap Combinations = (5, 2) (5, 3) (5, 4) (5, 4, 3, 2) (5, 4, 3, 1) (5, 4, 2, 1)
Sequence for (5, 2) Tap {1 1 1 1 1 0 0 1 1 0 1 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 1 1 0 0 0}
Sequence for (5, 3) Tap {1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0}
Sequence for (5, 4) Tap {1 1 1 1 1 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 0 0 0 0 1}
Sequence for (5, 4, 3, 2) Tap {1 1 1 1 1 0 0 1 0 0 1 1 0 0 0 0 1 0 1 1 0 1 0 1 0 0 0 1 1 10}
Sequence for (5, 4, 3, 1) Tap {1 1 1 1 1 0 1 0 0 0 1 0 0 1 0 1 0 1 1 0 0 0 0 1 1 1 0 0 1 10}
Sequence for (5, 4, 2, 1) Tap {1 1 1 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 10}

1.5 No of shift registrars = 6
Tap Combinations = (6, 1) (6, 5) (5, 1) (5, 4) (6, 5, 4, 1) (6, 5, 3, 2) (6, 5, 2, 1) (6, 4, 3, 1)
Sequence for (6, 1) Tap is {1 1 1 1 1 1 0 1 0 1 0 1 1 0 0 1 1 0 1 1 1 0 1 1 0 1 0 0 1 0 0 1 1 1 0 0 0 1 0 1 1 1 1 0 0 1 0 1 0 0 0 1 1 0 0 0 0 1 0 0 0 0 0}
Sequence for (6, 5) Tap is {1 1 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 1 0 0 1 1 1 1 0 1 0 0 0 1 1 1 0 0 1 0 0 1 0 1 1 0 1 1 1 0 1 1 0 0 1 1 0 1 0 1 0}
Sequence for (5, 1) Tap is {1 1 1 1 1 1 0 1 0 1 0 0 1 1 0 0 0 1 0 0 0 0 1 1 1 1 1 0 1 0 1 0 0 1 1 0 0 0 1 0 0 0 0 1 1 1 1 1 0 1 0 1 0 0 1 1 0 0 0 1 0 0 0}
Sequence for (5, 4) Tap is {1 1 1 1 1 1 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1}
Sequence for (6, 5, 4, 1) Tap is {1 1 1 1 1 1 0 1 0 1 1 1 0 0 0 1 1 0 0 1 1 1 0 1 1 0 0 0 0 0 1 1 1 1 0 0 1 0 0 1 0 1 0 1 0 0 1 1 0 1 0 0 0 0 1 0 0 0 1 0 1 1 0}
Sequence for (6, 5, 3, 2) Tap is {1 1 1 1 1 1 0 0 1 0 1 0 1 0 0 0 1 1 0 0 1 1 1 1 0 1 1 1 0 1 0 1 1 0 1 0 0 1 1 0 1 1 0 0 0 1 0 0 1 0 0 0 0 1 1 1 0 0 0 0 0 1 0}
Sequence for (6, 5, 2, 1) Tap is {1 1 1 1 1 1 0 1 1 0 1 0 0 0 1 0 0 0 0 1 0 1 1 0 0 1 0 1 0 1 0 0 1 0 0 1 1 1 1 0 0 0 0 0 1 1 0 1 1 1 0 0 1 1 0 0 0 1 1 1 0 1 0}
Sequence for (6, 4, 3, 1) Tap is {1 1 1 1 1 1 0 1 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 1 0 0 0 1 1 0 1 1 0 0 1 0 1 1 0 1 0 1 1 1 0 1 1 1 1 0 0 1 1 0 0 0 1 0 1 0 1 0 0}

1.6 No of shift registrars = 7
Tap Combinations = (7, 1) (7, 3) (7, 4) (7, 6) (7, 6, 5, 4) (7, 6, 5, 2) (7, 6, 4, 2) (7, 6, 4, 1) (7, 6, 3, 1) (7, 5, 4, 3) (7, 4, 3, 2) (7, 3, 2, 1) (7, 6, 5, 4, 3, 2) (7, 6, 5, 3, 2, 1) (7, 6, 5,

4, 2, 1) (7, 5, 4, 3, 2, 1)
Sequence for (7, 1) Tap is {1 1 1 1 1 1 1 0 1 0 1 0 1 0 0 1 1 0 0 1 1 1 0 1 1 1 0 1 0 0 1 0 1 1 0 0 0 1 1 0 1 1 1 1 0 1 1 0 1 0 1 1 0 1 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0 0 1 0 1 0 1 1 1 0 0 1 1 0 1 0 0 0 1 0 0 1 1 1 1 0 0 0 1 0 1 0 0 0 0 1 1 0 0 0 0 0 1 0 0 0 0 0 0}
Sequence for (7, 3) Tap is {1 1 1 1 1 1 1 0 0 0 1 1 1 0 1 1 0 0 0 1 0 1 0 0 1 0 1 1 1 1 1 0 1 0 1 0 1 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0 1 1 1 0 0 1 0 1 0 1 1 0 0 1 1 0 0 0 0 0 1 1 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 0 0 1 0 0 0 1 0 0 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 0 1 1 1 1 0 1 1 1 0 0 0 0}
Sequence for (7, 6, 5, 4) Tap is {1 1 1 1 1 1 1 0 0 0 0 1 0 1 0 1 1 0 0 0 1 0 0 1 1 1 1 0 0 1 0 1 0 0 1 0 0 1 0 1 1 0 1 0 1 0 1 0 0 0 0 0 1 1 0 0 1 0 0 0 0 1 1 1 0 1 0 1 1 1 0 0 1 1 1 0 0 0 1 1 0 1 1 0 0 1 1 0 0 0 0 0 0 1 0 0 0 1 1 1 1 1 0 1 0 0 1 1 0 1 0 0 0 1 0 1 1 1 1 0 1 1 0 1 1 1 0}
Sequence for (7, 6, 3, 1) Tap is {1 1 1 1 1 1 1 0 1 0 0 1 1 0 0 0 0 1 1 0 1 0 0 0 0 1 0 1 0 0 1 0 1 1 0 1 1 0 0 1 0 1 0 1 0 1 1 0 0 0 1 0 0 0 0 0 1 0 0 1 1 1 1 1 0 0 1 1 1 0 0 1 0 0 1 0 0 0 1 1 0 0 1 1 0 1 1 1 1 0 0 0 0 0 0 1 1 1 0 1 0 1 0 0 0 1 0 1 1 1 0 0 0 1 1 1 1 0 1 1 1 0 1 1 0 1 0}
Sequence for (7, 3, 2, 1) Tap is {1 1 1 1 1 1 1 0 1 1 1 0 1 1 0 1 1 1 1 0 1 0 0 0 1 0 1 1 0 0 1 0 1 1 1 1 1 0 0 0 1 0 0 0 0 0 0 1 1 0 0 1 1 0 1 1 0 0 0 1 1 1 0 0 1 1 1 0 1 0 1 1 1 0 0 0 0 1 0 0 1 1 0 0 0 0 0 1 0 1 0 1 0 1 1 0 1 0 0 1 0 0 1 0 1 0 0 1 1 1 1 0 0 1 0 0 0 1 1 0 1 0 1 0 0 0 0}
Sequence for (7, 6, 5, 4, 3, 2) Tap is {1 1 1 1 1 1 1 0 0 1 0 0 1 0 0 0 0 1 1 0 0 0 0 0 0 1 0 1 1 0 1 1 0 0 0 1 0 1 0 0 0 0 0 1 1 1 0 1 1 0 1 0 0 1 1 1 1 0 0 0 0 1 0 0 1 1 0 1 1 1 0 1 0 0 0 1 0 0 0 1 1 0 1 0 1 1 0 0 1 1 1 0 0 1 1 0 0 1 0 1 1 1 1 0 1 0 1 0 0 1 0 1 0 1 0 1 1 1 0 0 0 1 1 1 1 1 0}
Sequence for (7, 5, 4, 3, 2, 1) Tap is {1 1 1 1 1 1 1 0 1 1 1 1 1 0 0 0 1 1 1 0 1 0 1 0 1 0 0 1 0 1 0 1 1 1 1 0 1 0 0 1 1 0 0 1 1 1 0 0 1 1 0 1 0 1 1 0 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 1 0 1 1 0 1 1 1 0 0 0 0 0 1 0 1 0 0 0 1 1 0 1 1 0 1 0 0 0 0 0 0 1 1 0 0 0 0 1 0 0 1 0 0}
So on…….

1.7 No of shift registrars = 8

Tap Combinations = (8, 3) (7, 5) (8, 7, 6, 5) (8, 7, 6, 1) (8, 6, 5, 4) (8, 6, 5, 3) (8, 6, 5, 2) (8, 6, 5, 1) (8, 4, 3, 2) (7, 6, 5, 1) (7, 5, 4, 1) (8, 5, 3, 1) (8, 5, 3, 2) (8, 4, 3, 2) (8, 6, 4, 3, 2, 1) (8, 7, 6, 5, 4, 2) (8, 7, 6, 5, 2, 1) (8, 7, 6, 3, 2, 1)
Sequence for (8, 3) Tap is {1 1 1 1 1 1 1 1 0 0 0 1 1 1 0 0 1 0 0 0 1 1 0 1 0 0 1 0 1 0 0 0 0 0 1 0 1 1 0 1 1 0 0 1 1 1 1 0 0 1 0 1 0 1 0 0 1 1 0 0 1 1 0 1 0 1 1 0 0 0 0 1 0 1 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 1 0 0 1 0 1 1 0 0 1 0 1 1 1 0 1 1 1 1 0 0 0 0 1 1 1 0 1 1 0 1 0 1 0 0 0 1 0 1 1 1 1 1 1 0 1 0 1 0 1 0 1 1 1 1 0 1 0 0 0 1 1 1 1 0 1 1 0 0 0 1 1 0 0 0 0 0 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1 1 0 0 1 1 0 0 0 1 0 0 0 1 0 0 1 1 0 1 1 1 1 1 0 0 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 1 1 1 0 0 1 0 0 0 1 1 0 1 0 0 1 0 1 0 0 0 0 0 1 0 1 1}
Sequence for (8, 7, 6, 5) Tap is {1 1 1 1 1 1 1 1 0 0 0 0 0 1 0 1 0 0 1 1 0 0 1 0 0 0 0 0 1 1 1 0 0 1 0 1 1 0 0 1 0 1 0 0 0 1 0 0 1 1 1 1 1 0 0 1 0 0 1 0 0 1 1 0 1 1 0 0 0 1 1 0 0 1 1 0 0 0 0 0 0 0 1 0 0 0 0 1 1 1 1 0 1 0 1 0 1 1 0 0 0 0 1 0 0 1 0 1 1 1 0 1 0 1 1 1 1 0 0 1 1 0 1 0 0 0 0 1 0 1 1 0 1 1 0 1 0 1 1 0 1 0 0 1 0 1 0 1 0 1 0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 1 1

1 1 1 1 0 1 0 0 0 1 1 0 1 1 1 0 0 1 1 1 1 0 0 0 1 0 1 0 1 1 1 0 0 0 1 1 1 0 1 1 0 1 1 1 1 0 1 1 1 0 1 1 1 1 1 1 1 1 0 0 0 0 0 1 0 1 0 0 1 1 0 0 1 0 0 0 0 0 1 1 1 0 0 1 0 1 1 0}
Sequence for (8, 6, 5, 3) Tap is {1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1 0 1 0 1 0 1 0 0 0 0 1 0 0 0 0 1 1 0 0 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 1 0 1 1 1 1 1 1 0 1 0 1 0 0 1 0 1 1 0 1 0 1 0 1 1 0 0 1 1 1 0 0 1 0 0 1 1 0 0 1 0 0 0 1 0 1 1 1 0 0 0 1 0 0 0 1 1 1 1 0 0 1 0 1 1 1 1 0 0 0 0 1 0 1 0 0 0 1 1 0 1 0 1 1 1 1 1 0 0 1 1 1 1 0 1 1 0 0 1 0 1 0 1 1 1 0 1 0 1 1 0 1 1 1 0 0 1 1 0 1 0 0 1 1 0 1 1 0 1 0 0 0 1 0 0 1 1 1 0 1 1 0 1 1 0 0 0 0 1 1 1 0 1 0 0 1 0 0 1 0 0 0 0 0 1 0 1 1 0 0 0 1 1 1 0 0 0 0 0 0 1 1 0 1 1 1 1 0 1 0 0 0 0 0 0 0 1 0 0 1 0 1 0 0}
Sequence for (8, 6, 4, 3, 2, 1) Tap is {1 1 1 1 1 1 1 0 1 1 1 1 0 0 0 0 0 0 1 0 1 0 0 1 1 0 0 0 0 1 0 0 0 1 1 1 1 1 0 0 1 0 1 0 1 1 0 0 0 1 1 1 0 0 0 0 1 1 1 0 1 1 0 1 1 0 0 1 1 0 1 0 1 1 0 1 1 1 1 1 1 0 0 0 1 1 0 1 0 0 0 0 1 1 0 1 1 1 0 0 1 0 0 1 1 1 0 1 0 1 1 1 0 1 1 1 0 1 0 0 0 1 0 1 0 1 0 1 0 0 1 0 1 0 0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 1 1 1 1 0 1 0 1 0 0 0 1 1 0 0 1 0 0 0 0 1 0 1 1 1 1 1 0 1 0 0 1 0 0 1 0 0 0 1 0 0 1 1 0 1 1 0 1 0 1 0 1 1 1 1 0 1 1 0 0 0 0 0 1 0 0 1 0 1 1 1 0 0 0 1 0 1 1 0 0 1 0 1 1 0 1 0 0 1 1 1 1 0 0 1 1 0 0 1 1 1 0 0}
Sequence for (8, 7, 6, 3, 2, 1) Tap is {1 1 1 1 1 1 1 0 1 1 1 0 1 0 1 0 0 1 1 1 1 0 1 1 0 1 1 0 0 1 1 0 0 1 0 0 1 1 1 0 1 1 1 1 0 0 1 1 1 0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 0 0 0 1 1 0 0 0 0 1 1 0 1 0 1 1 0 0 1 0 1 0 1 1 1 0 0 0 0 0 1 1 1 1 1 1 0 0 0 1 0 0 1 0 1 1 1 0 1 1 0 0 0 0 0 0 0 1 1 0 0 1 1 1 1 1 0 1 0 0 0 1 1 0 1 1 0 1 0 1 0 1 0 1 1 0 1 0 0 1 1 0 0 0 1 0 1 0 0 1 0 0 1 0 0 0 1 0 0 0 1 1 1 0 1 0 0 1 0 1 0 0 0 1 0 1 1 1 1 0 1 0 1 1 1 1 1 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 0 1 1 0 1 1 1 0 0 1 1 0 1 0 0 0 0 0 0 1 0 1 0 1 0 0 0 0 1 1 1 0 0 1 0 1 1 0}
So on…….
Likewise maximal codes can be generated for feedback shift registrars of 9, 10, 11, ….

2. GOLD SEQUENCES:

set of gold codes is given by two different maximal sequence of same length (*c*, *c*’). The modulo-2 sums of *c* and all *M* different cyclically shifted versions of *c*’, hence *M + 2* codes [1]

2.1 No of shift registrars = 3

Gold sequence tap combinations: (1, 3) (2, 3)
Gold sequences are: {0 0 0 0 1 1 0} {1 0 0 1 1 0 1} {0 1 0 1 0 0 0} {1 0 1 1 0 1 0} {1 1 0 0 0 1 1} {0 1 1 1 1 1 1} {0 0 1 0 0 0 1}
No. of gold sequences = 7+2 = 9
No. of balanced gold codes = 3+2 and No. of unbalanced codes = 4

2.2 No of shift registrars = 4

Gold sequence tap combinations = (4, 1) (4, 2)
Gold sequences are: {0 0 0 0 0 1 1 0 0 1 0 1 1 1 1} {0 0 0 0 1 1 0 0 0 1 1 1 0 1 1} {0 0 0 0 1 0 0 1 0 1 1 0 0 0 1} {0 0 0 0 1 0 1 1 1 1 1 0 1 0 0}{1 0 0 0 1 0 1 0 1 0 1 0 1 1 0} {1 1 0 0 1 0 1 0 0 0 0 0 1 1 1} {0 1 1 0 1 0 1 0 0 1 0 1 1 1 1} {0 0 1 1 1 0 1 0 0 1 1 1 0 1 1} {0 0 0 1 0 0 1 0 0 1 1 0 0 0 1} {0 0 0 0 0 1 1 0 0 1 1 0 1 0 0} {1 0 0 0 1 1 0 0 0 1 1 0 1 1 0} {1 1 0 0 1 0 0 1 0 1 1 0 1 1 1} {0 1 1 0 1 0 1 1 1 1 1 0 1 1 1} {0 0 1 1 1 0 1 0 1 0 1 0 1 1 1} {0 0 0 1 0 0 1 0 0 0 0 0 1 1 1}
No. of gold sequences = 15+2 = 17

In 17 gold codes of length 15, No of balanced gold codes = 5+2 and No. of unbalanced gold codes = 10

2.3 No of shift registrars = 5

Gold sequence tap combinations sets = {(5, 2) (5, 3)} {(5, 2) (5, 4)} {(5, 3) (5, 4)} {(5, 2) (5, 4, 3, 2)} {(5, 2) (5, 4, 3, 1)} {(5, 2) (5, 4, 2, 1)} {(5, 3) (5, 4, 3, 2)} {(5, 3) (5, 4, 3, 1)} {(5, 3) (5, 4, 2, 1)} {(5, 4) (5, 4, 3, 2)} {(5, 4) (5, 4, 3, 1)} {(5, 4) (5, 4, 2, 1)} {(5, 4, 3, 2) (5, 4, 3, 1)} {(5, 4, 3, 2) (5, 4, 2, 1)} {(5, 4, 3, 1) (5, 4, 2, 1)}

15 sets of taps in total

Each set of produces (31+2) 33 gold codes

With 5 length linear feedback shift registrar = (15*31) + 6 = 471 gold codes are possible.

In 471 gold codes of length 31, No of balanced gold codes = 168+6 and No. of unbalanced gold codes = 297

Gold sequences for {(5, 2) (5, 3)}

{1 1 1 1 1 0 0 1 1 0 1 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 1 1 0 0 0}
{1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0 0}
{0 0 0 0 0 0 0 1 0 1 1 1 1 0 0 1 0 1 1 0 1 0 0 1 1 1 1 0 1 0 0}
{1 0 0 0 0 1 0 1 1 1 0 0 1 0 1 0 1 0 0 0 1 0 1 0 1 0 0 1 1 1 0}
{1 1 0 0 0 1 1 1 1 0 0 1 0 0 1 1 0 1 1 1 1 0 1 1 0 0 1 0 0 1 1}
{0 1 1 0 0 1 1 0 1 0 1 1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 0 1}
{0 0 1 1 0 1 1 0 0 0 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 0 0 1 0 1 0}
{1 0 0 1 1 1 1 0 0 1 1 0 0 0 1 0 1 1 0 0 0 0 0 1 1 0 1 0 0 0 1}
{0 1 0 0 1 0 1 0 0 1 0 0 0 1 1 1 0 1 0 1 1 1 1 0 1 0 1 1 1 0 0}
{1 0 1 0 0 0 0 0 0 1 0 1 0 1 0 1 1 0 0 1 0 0 0 1 0 0 1 1 0 1 0}
{1 1 0 1 0 1 0 1 0 1 0 1 1 1 0 0 1 1 1 1 0 1 1 0 1 1 1 1 0 0 1}
{0 1 1 0 1 1 1 1 1 1 0 1 1 0 0 0 0 1 0 0 0 1 0 1 0 0 0 1 0 0 0}
{1 0 1 1 0 0 1 0 1 0 0 1 1 0 1 0 0 0 0 1 1 1 0 0 1 1 1 0 0 0 0}
{1 1 0 1 1 1 0 0 0 0 1 1 1 0 1 1 0 0 1 1 0 0 0 0 0 0 0 1 1 0 0}
{1 1 1 0 1 0 1 1 0 1 1 0 1 0 1 1 1 0 1 0 0 1 1 0 0 1 1 0 0 1 0}
{1 1 1 1 0 0 0 0 1 1 0 0 0 0 1 1 1 1 1 0 1 1 0 1 0 1 0 1 1 0 1}
{0 1 1 1 1 1 0 1 0 0 0 1 0 1 1 1 1 1 0 0 1 0 0 0 1 1 0 0 0 1 0}
{1 0 1 1 1 0 1 1 1 1 1 1 1 0 1 1 1 0 1 1 0 1 0 0 0 0 0 1 0 1}
{1 0 1 1 0 0 0 1 0 0 0 1 0 0 0 1 1 0 1 0 0 1 1 0 1 1 0 1 1 0 1}
{1 0 1 0 1 0 0 1 0 0 1 1 0 0 1 0 0 1 0 1 0 1 1 1 1 1 0 1 1 1 1}
{0 1 0 1 0 0 0 1 1 1 1 0 1 1 1 1 0 0 0 1 0 1 0 1 1 0 0 0 0 1 1}
{0 0 1 0 1 1 0 1 1 0 0 0 0 0 0 1 1 0 1 1 0 1 0 0 1 0 1 0 1 0 1}
{0 0 0 1 0 0 1 1 1 0 1 1 0 1 1 0 1 1 1 0 0 1 0 0 0 0 1 1 1 1 0}
{1 0 0 0 1 1 0 0 1 0 1 0 1 1 0 1 0 1 0 0 1 1 0 0 0 1 1 1 0 1 1}
{0 1 0 0 0 0 1 1 0 0 1 0 0 0 0 0 1 0 0 1 1 0 0 0 0 1 0 1 0 0 1}
{0 0 1 0 0 1 0 0 1 1 1 0 0 1 1 0 0 1 1 1 0 0 1 0 0 1 0 0 0 0 0}
{1 0 0 1 0 1 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 0 0}
{1 1 0 0 1 1 1 0 1 1 1 1 0 1 0 0 1 0 1 1 1 1 0 1 1 1 0 0 1 1 0}
{1 1 1 0 0 0 1 0 0 0 0 0 1 1 0 0 0 1 1 0 0 0 0 0 1 0 0 0 1 1 1}
{0 1 1 1 0 1 0 0 0 1 1 1 0 0 0 0 0 0 0 0 1 1 1 0 0 0 1 0 1 1 1}

{0 0 1 1 1 1 1 1 0 1 0 0 1 1 1 0 0 0 1 1 1 0 0 1 0 1 1 1 1 1 1}
{0 0 0 1 1 0 1 0 1 1 0 1 0 0 0 1 0 0 1 0 0 0 1 0 1 1 0 1 0 1 1}
{0 0 0 0 1 0 0 0 0 0 0 1 1 1 1 0 1 0 1 0 1 1 1 1 0 0 0 0 0 0 1}
Similarly, we can obtain the 31 length gold sequences for other tap combinations

2.4 No of shift registrars = 6

Gold sequence tap combinations sets = {(6, 1) (6, 5, 4, 1)} {(6, 1) (6, 5, 3, 2)} {(6, 1) (6, 5, 2, 1)} {(6, 1) (6, 4, 3, 1)} {(6, 5) (6, 5, 4, 1)} {(6, 5) (6, 5, 3, 2)} {(6, 5) (6, 5, 2, 1)} {(6, 5) (6, 4, 3, 1)} {(5, 1) (6, 5, 4, 1)} {(5, 1) (6, 5, 3, 2)} {(5, 1) (6, 5, 2, 1)} {(5, 1) (6, 4, 3, 1)} {(5, 4) (6, 5, 4, 1)} {(5, 4) (6, 5, 3, 2)} {(5, 4) (6, 5, 2, 1)} {(5, 4) (6, 4, 3, 1)}{(6, 1) (6, 5)} {(6, 1) (5, 1)} {(6, 1) (5, 4)} {(6, 5) (5, 1)} {(6, 5) (5, 4)} {(5, 1) (5, 4)} {(6, 5, 4, 1) (6, 5, 3, 2)} {(6, 5, 4, 1) (6, 5, 2, 1)} {(6, 5, 4, 1) (6, 5, 3, 1)} {(6, 5, 3, 2) (6, 5, 2, 1)} {(6, 5, 3, 2) (6, 4, 3, 1)} {(6, 5, 2, 1) (6, 4, 3, 1)}
28 sets of taps in total
Each set of produces (63+2) 65 gold codes
With 6 length linear feedback shift registrar = (28*63) +8 = 1764 gold codes are possible.
In 1764 gold codes of length 63, No of balanced gold codes = 629 and No. of unbalanced gold codes = 1135

2.5 No of shift registrars = 7

Tap Combinations = (7, 1) (7, 3) (7, 4) (7, 6) (7, 6, 5, 4) (7, 6, 5, 2) (7, 6, 4, 2) (7, 6, 4, 1) (7, 6, 3, 1) (7, 5, 4, 3) (7, 4, 3, 2) (7, 3, 2, 1) (7, 6, 5, 4, 3, 2) (7, 6, 5, 3, 2, 1) (7, 6, 5, 4, 2, 1) (7, 5, 4, 3, 2, 1)
120 sets of taps in total i.e., {(7, 1) (7, 3)} {(7, 1) (7, 4)}{(7, 1) (7, 6)}{(7, 1) (7, 6, 5, 4)}{(7, 1) (7, 6, 5, 2)}……so on
Each set of produces (127+2) 129 gold codes
With 7 length linear feedback shift registrar = (120*127) +16 = 15256 gold codes are possible.
In 15256 gold codes of length 127, some codes are balanced gold codes and some are unbalanced gold codes

2.6 No of shift registrars = 8

Tap Combinations = (8, 3) (7, 5) (8, 7, 6, 5) (8, 7, 6, 1) (8, 6, 5, 4) (8, 6, 5, 3) (8, 6, 5, 2) (8, 6, 5, 1) (8, 4, 3, 2) (7, 6, 5, 1) (7, 5, 4, 1) (8, 5, 3, 1) (8, 5, 3, 2) (8, 4, 3, 2) (8, 6, 4, 3, 2, 1) (8, 7, 6, 5, 4, 2) (8, 7, 6, 5, 2, 1) (8, 7, 6, 3, 2, 1)
171 sets of taps in total i.e., {(8, 3) (7, 5)} {(8, 3) (8, 7, 6, 5)} {(8, 3) (8, 7, 6, 1)} {(8, 3) (8, 6, 5, 4)} {(8, 3) (8, 6, 5, 3) and so on
Each set of produces (255+2) 257 gold codes
With 8 length linear feedback shift registrar = (171*255) +19 = 43624 gold codes are possible.
In 43624 gold codes of length 255, some codes are balanced gold codes and some are unbalanced gold codes
Likewise gold codes can be generated for feedback shift registrars of 9, 10, 11, ….

3 KASAMI CODES

Starting from an *m*-sequence c_0, the corresponding decimated sequence is C_d obtained by taking every d^{th} chip from C_0 where $d = 2k + 1$ for a Kasami code generation and repeating these $2k - 1$ chips $2k + 1$ times. The resulting code sequence C_d has the same length as C_0 but a period of $2k - 1$. [2]

•The set of Kasami codes is constructed in a similar way as the set of gold codes by taking C_0 and the modulo-2 sum of C_0 and all $2k - 1$ cyclically shifted versions of C_d.

3.1 No. of shift registrars = 2

Tap Combinations = (1, 2)
Maximal Sequence for (1, 2) Tap {0 1 1}
Decimated sequence $C_{d\,=}$ {1 1 1}
Kasami sequence are k1 = {1 0 0}

3.2 No of shift registrars = 4

Tap Combinations = (4, 1) (4, 2)
M-Sequence for (4, 1) Tap {0 0 0 1 1 1 1 0 1 0 1 1 0 0 1}
Decimated sequence $C_{d\,=}$ {1 0 1 1 0 1 1 0 1 1 0 1 1 0 1}
Kasami sequence k1 = {1 0 1 0 1 0 0 0 0 1 1 0 1 0 0} M sequence XOR with decimated sequence
Kasami sequence k2 = {1 1 0 0 0 1 0 1 1 1 0 1 1 1 1} M sequence XOR with one-bit shifted version of decimated sequence
Kasami sequence k3 = {0 1 1 1 0 0 1 1 0 0 0 0 0 1 0} M sequence XOR with two-bit shifted version of decimated sequence
M-Sequence for (4, 2) Tap {0 0 0 1 0 0 1 1 0 1 0 1 1 1 1}
Decimated sequence $C_{d\,=}$ {0 1 1 0 1 1 0 1 1 0 1 1 0 1 1}
Kasami sequence k1 = {0 1 1 1 1 1 1 0 1 1 1 0 1 0 0} M sequence XOR with decimated sequence.
Kasami sequence k2 = {1 0 1 0 0 1 0 1 1 0 0 0 0 1 0} M sequence XOR with one-bit shifted version of decimated sequence.
Kasami sequence k3 = {1 1 0 0 1 0 0 0 0 0 1 1 0 0 1} M sequence XOR with two-bit shifted version of decimated sequence.
In case of four length shift registrar three Kasami sequences are possible for each maximal sequence.
Therefore total 6 Kasami sequences

3.3 No of shift registrars = 6

Tap Combinations = (6, 1) (6, 5) (5, 1) (5, 4) (6, 5, 4, 1) (6, 5, 3, 2) (6, 5, 2, 1) (6, 4, 3, 1)
M Sequence for (6, 1) Tap is {0 0 0 0 0 1 1 1 1 1 1 0 1 0 1 0 1 1 0 0 1 1 0 1 1 1 0 1 1 0 1 0 0 1 0 0 1 1 1 0 0 0 1 0 1 1 1 1 0 0 1 0 1 0 0 0 1 1 0 0 0 0 1}
Decimated sequence C_d = {1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1 1 1 0 0 1 0 1}
Kasami sequence K1 = {1 1 0 0 1 1 0 0 0 1 1 1 1 1 0 1 1 1 1 0 0 0 1 1 1 0 0 0 0 1 1 0 1 1 1 1 0 1 1 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 0 1 0 0 0 0 1 0 0} M sequence XOR with

decimated sequence.
Kasami sequence K2 = {1 1 1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 0 1 0 1 1 1 1 0 1 0 0 0 0 0 1 0 0 1 0 1 0 0 1 0 1 1 0 0 1 0 1 1 0 1 0 0 0 1 0 0 1 1} M sequence XOR with one-bit shifted decimated sequence.
Kasami sequence K3 = {0 1 1 1 0 1 0 1 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 0 0 1 0 0 1 1 0 1 0 1 1 0 0 0 0 0 0 1 1 1 0 0 1 1 1 0 0 1 0 0 0 1 1 0 1 1 0 0 0} M sequence XOR with two-bit shifted decimated sequence
Kasami sequence K4 = {1 0 1 1 1 1 1 0 1 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 0 0 0 1 1 1 0 1 1 0 0 1 0 0 0 0 0 0 0 1 0 1 1 1 0 1 0 0 0 1 1 1 1 0 1}M sequence XOR with three bit shifted decimated sequence
Kasami sequence K5 = {0 1 0 1 1 0 1 1 0 1 0 1 0 0 1 1 1 0 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 0 0 0 0 1 0 1 1 0 1 1 1 0 0 0 0 0 0 0 0 1 1 0 1 0 0 1 1 1 1} M sequence XOR with four bit shifted decimated sequence
Kasami sequence K6 = {0 0 1 0 1 0 0 1 1 0 1 1 0 1 1 0 0 1 1 1 0 1 0 0 1 0 1 0 1 0 0 0 1 0 1 0 1 0 1 1 1 1 1 0 0 1 0 0 1 0 1 1 1 1 1 1 1 1 1 0 1 1 0} M sequence XOR with five bit shifted decimated sequence
Kasami sequence is K7 = {1 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 1 0 0 1 0 0 0 1 0 1 1 0 0 0 1 1 0 0 1 1 1 1 0 0 1 1 0 0 1 0 1 0 1 1 1 0 0 0 1 1 0 1 0 1 0 1 0} M sequence XOR with six bit shifted decimated sequence
Similarly for remaining taps seven different m sequences are possible. With each maximal sequence 7 Kasami codes are generated. Therefore, total Kasami sequences possible for 6 length shift registrar is 56.

4 SEQUENCE COMPARISON

Table1: Comparison of PN Sequences for different length Shift Registrars

No of Shift Registrars	Length of code	No of maximal sequences	No of gold codes	No of Kasami codes
2	3	1	Nil	1
3	7	2	9	Nil
4	15	2	17	6
5	31	6	471	Nil
6	63	8	1764	56
7	127	16	15256	Nil
8	255	18	39033	270
9	511	48	57576	Nil
10	1023	60	1810770	1860

5. CONCLUSION

For a fixed length shift registrar, the number of gold codes are very large but those codes exhibit poor auto correlation. Kasami sequences are not possible to generate with odd length shift registrars.

6. REFERENCES:

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