International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com ‖ PP. 175-180

Spread Spectrum Coded OFDM chirp waveform Scheme For RADAR Application

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ABSTRACT: OFDM (Orthogonal Frequency Division Multiplexing) is a genuine multiplexing method with its application in the area of wideband digital communication. The Sub-carriers in the system are exploited for data transmission. Preserving the orthogonality of the waveforms till it reaches the receiver is a must. Chirp waveform is used in OFDM modulation and then it is spread spectrum coded to obtain a new waveform diversity design. Earlier methods for waveform diversity design were also proposed. But the proposed techniques faced problems. They only gave satisfactory performance pertaining to target detection, they also suffered with loss of orthogonality as they are propagated. Hence there was a need for the novel method of waveform design, that is done with the combination of DSSS, chirp signal, and OFDM. Here the interpretation regarding the efficiency of designed waveforms is done upon investigating ambiguity function plot**.**

KEYWORDS: Ambiguity function, Chirp Waveform, Orthogonal Frequency Division Multiplexing, Spread Spectrum coding, Waveform Diversity

I. INTRODUCTION

The RADAR technology is gaining more importance because its application is pertaining to safety and security supplications. Considering the waveform design part, it is very much necessary that the designed waveforms must remain orthogonal even at the receiver. For this criteria to be satisfied the design of the waveform must be efficient. If the designed waveform has a better orthogonality property and better Doppler frequency shift resistant property then the waveform can be called as efficient. Many of the research works is been done pertaining to RADAR waveform design. Earlier methods were polarization diverse waveform, phase coded waveform, a method that uses both of these and pulse compression technique. In those earlier methods there was loss in orthogonality which leads poor performance pertaining to target detection. Hence a novel method was proposed [1] to design efficient orthogonal waveforms, but that generated only two orthogonal waveform set. Generation of more orthogonal sets is proposed in this paper. The designed waveforms have a redused cross ambiguity response when compared to earlier methods which proves that the proposed method is efficient. OFDM is a multiplexing scheme where in the available bandwidth is divided in to sub-carriers across which the data is transmitted. Synchronization is a major problem in case of OFDM [2]. But since RADAR uses stored version of waveform for transmission, this issue won't come in to picture. Chirp signal can be referred as a compressed pulse. If the pulse is of short duration then it can get a better resolution, but the RADAR targets will be of larger distance. And short duration pulses will not be capable of travelling larger distance. Since the chirp signal will be compressed, it will be of short duration like a pulse but will be efficient to reach the targets at longer distance[4]. Ambiguity function is used to evaluate the designed waveform. Ambiguity function is a two dimensional function. It is a function of delay and Doppler frequency. This function evaluates the returned waveform for the presence of distortion in it. It is represented as $|\chi(\tau, f)|$ where τ is the time delay and f is the Doppler frequency.

II. OFDM Chirp Modulation

Input Spectrum is considered and the spectrum is sampled in frequency domain. The sampled data is interleaved with zeros and then transformation to time domain with the aid of Inverse Discrete Fourier Transform (IDFT) which generates the chirp signal S1(t) in time domain[10]. To generate the remaining three OFDM chirp waveforms the interleaved sequence is shifted by $\Delta f/2$, Δf, $3\Delta f/2$ respectively to generate S2(t), S3(t) and S4(t) respectively. These are again performed with IDFT process to generate time domain chirp signal. Sub-carriers number is 4N in all the sets, but N sub-carriers are exploited. For analysis purpose only S1(t) and S2(t) are considered.

The time domain discrete samples are represented by:

$$s[m] = e^{(j\pi kr\,(mTs)2)}, \quad m = 0,1,\dots\dots..N-1 \qquad (1)$$

Where *Ts* is the sampling interval and *kr* is the chirp rate. *kr = B/Tp*. Where B is the Bandwidth and Tp is the duration of chirp. Upon performing Fourier transform to equation (1) the resultant is as mentioned in equation (2).

$$S[p] = \mathcal{F} = \mathcal{F}\{e^{(j\pi kr\ (mTs)2)}\} \quad (2)$$

Where $\mathcal{F}\{.\}$ is the Fourier transform operator. With the input as S[p], the time domain waveform is given by equation (3) :

$$s1[n] = \frac{1}{4}\left\{s[n]rect\left[\frac{n}{N}\right] + s[n-N]rect\left[\frac{n-N}{N}\right] + s[n-2N]rect\left[\frac{n-2N}{N}\right] + s[n-3N]rect\left[\frac{n-3N}{N}\right]\right\} \quad (3)$$

Where n= 0,1,…,4N-1.

If Δf = *1/2NTs*, the amount of shift in subcarrier sets is $\Delta f/2$ and hence the remaining three waveforms can be obtained at a stretch from the equation 4.

$$si[n] = s1[n]\exp\left(\frac{j(i-1)\Pi n}{2N}\right), \quad i = 2,3,4\ldots \quad (4)$$

This can be represented in continuous - time domain representation as equation 5,

$$s1(t) = 1/4\left\{s(t)rect\left[\frac{t}{Tp}\right] + s(t-Tp)rect\left[\frac{t-Tp}{Tp}\right] + s(t-2Tp)rect\left[\frac{t-2Tp}{Tp}\right] + s(t-3Tp)rect\left[\frac{t-3Tp}{Tp}\right]\right\}$$

$$si(t) = s1(t)\exp\left(\frac{j\Pi(it)}{4Tp}\right), i = 2,3,4 \quad (5)$$

Further, from the above signals the signals S1(t) and S2(t) are considered for Spread Spectrum Coding. That is they are taken up for further DSSS modulation and the resultant signals are represented by the equation 6 and 7.

$$sc1(t) = \sum_{m}^{M-1} Cm\,P(t - mTc)s1(t) \quad (6)$$

$$sc2(t) = \sum_{n}^{M-1} Dn\,P(t - nTc)s2(t) \quad (7)$$

Where Cm and Dn are the two pseudo random sequence

III. Waveform Performance Analysis

Table I Simulation Parameter Requirements

PARAMETERS	REQUIRED MEASUREMENTS
Bandwidth(B)	4MHz
Pulse Duration(Tp)	1µs
Chirp Rate(Kr)	B/Tp
Code Length	2^m or $2^{m-1}(m = 2,3,4,5,6,7)$

1. Impact of Spread Spectrum Code length

When *B* = 4 MHz, the BWs of 20 *MHz*, 36 *MHz*, 68 *MHz*, 132 *MHz*, 260 *MHz* and 516 *MHz* correspond to the code lengths of 4, 8, 16, 32, 64 and 128, respectively. Walsh-Hadamard code is considered for all experimental pupose. Table II provides the maximal cross-ambiguity function (CAF) for different code length. It is observed that, as the code length is longer lesser the CAF value and hence better orthogonality performance.

Table II CAF table for different code lengths and bandwidth for proposed system

Code type	Code length	BW (MHz)	Max {CAF} (Proposed)
-	1	4	0.41921
Walsh	4	20	0.41595
Walsh	8	36	0.40519
Walsh	16	68	0.40279
Walsh	32	132	0.39184
Walsh	64	260	0.33784
Walsh	128	516	0.27875

2. Impact of Spread Spectrum Code Type

Different types of Spread Spectrum Codes are taken into consideration namely, Walsh Hadamard code, *m* sequence, Gold sequence and orthogonal GOLD sequence. For Walsh-Hadamard code and orthogonal GOLD sequence, the code lengths are $2l$ $(l = 2, 3, 4, 5, 6, 7)$, and the code- length of $2l - 1$ is used for the m and Gold sequences. It is noticed that, GOLD sequence proves to be the best in orthogonality performance.

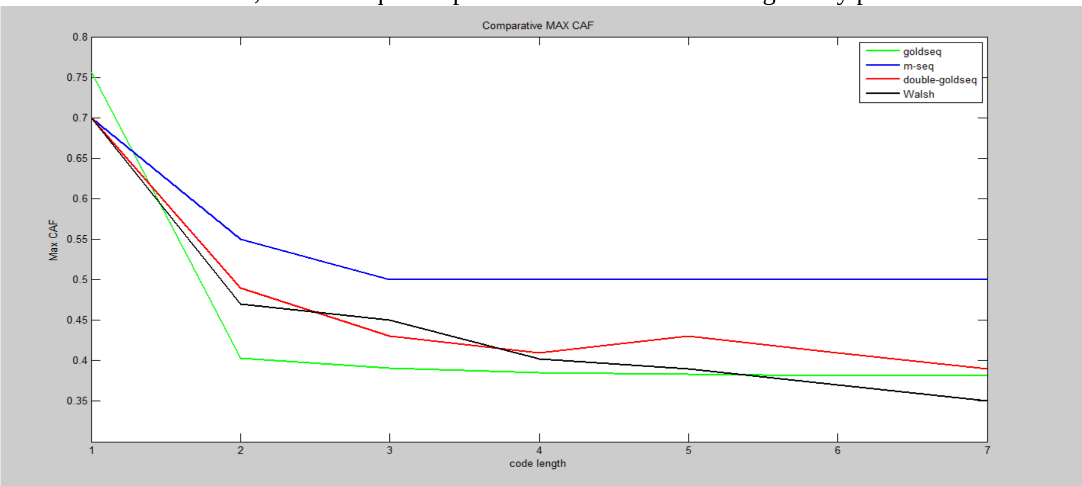

Fig 1: Comparitive max {CAF} among different codes

The methodology followed must yield in a valid result which is analyzed and discussed in this section. The results obtained are as follows. OFDM chirp waveforms *s*1*(t)*, *s*2*(t)* and SS coded waveforms are considered for analysis.

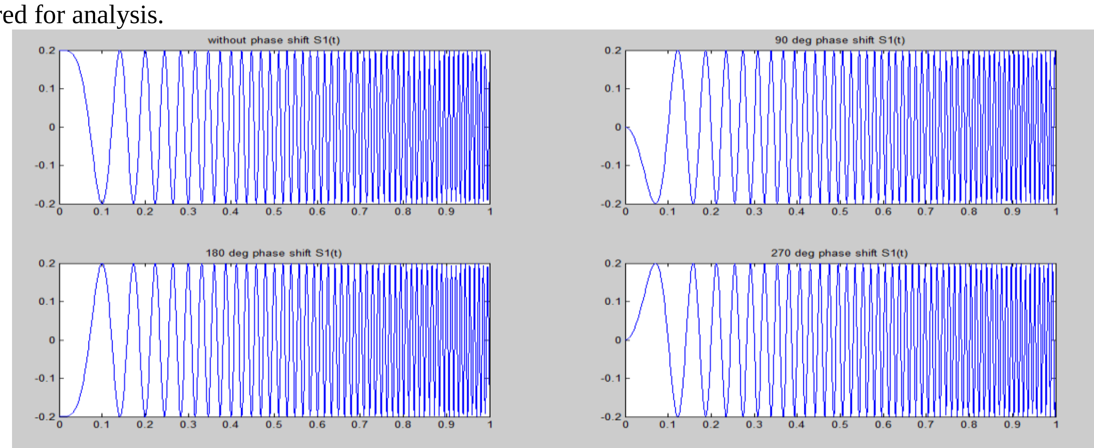

Fig 2: Generated chirp signals along with phase shifts

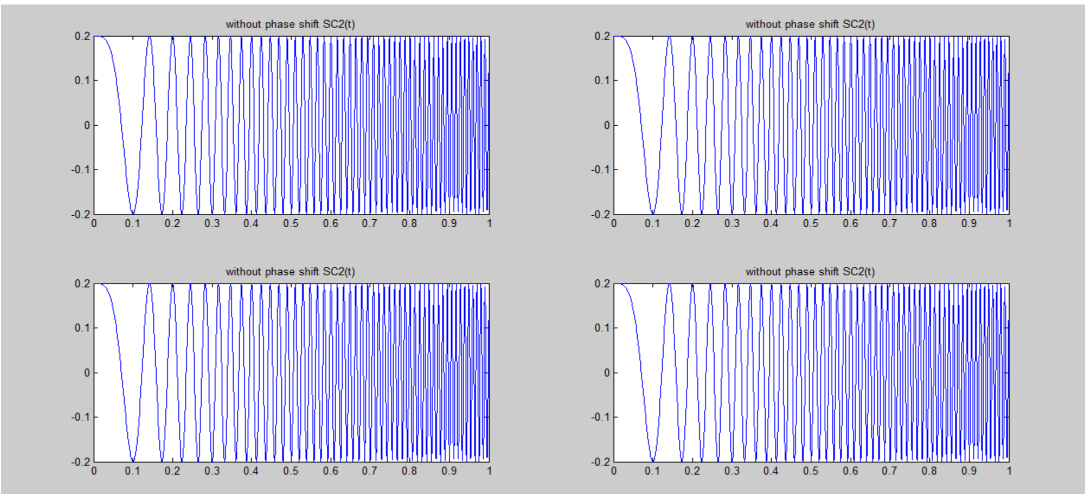

Fig 3: Chirp signals done with DSSS modulation

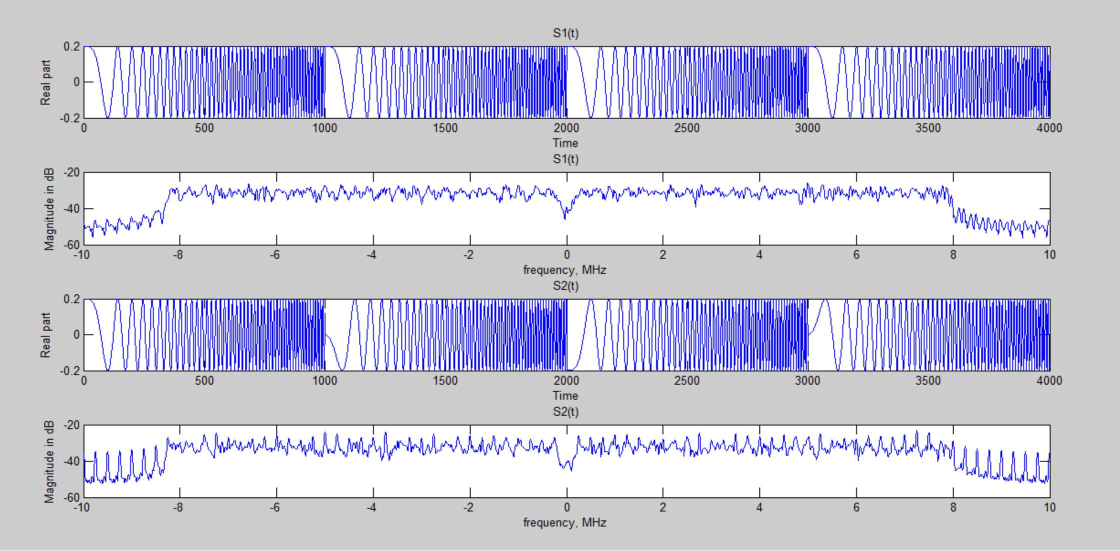

Fig 4: Chirp Signals along with magnitude Spectrum

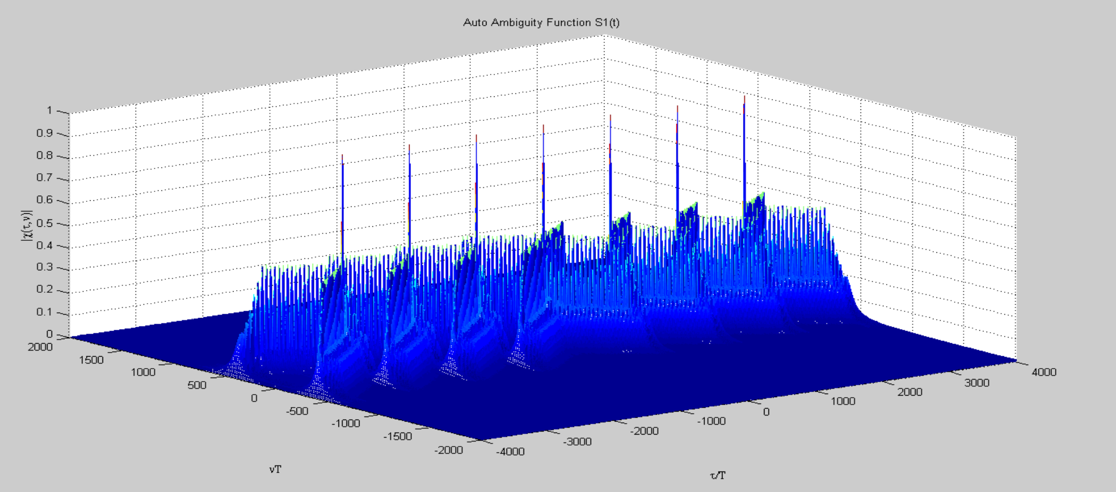

Fig 5: Auto ambiguity function of S1(t)

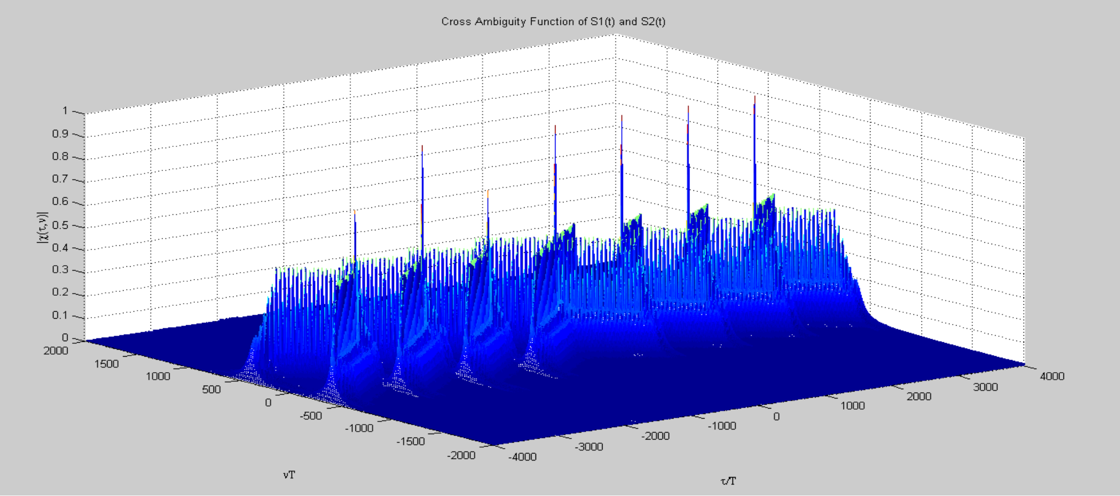

Fig 6: Cross Ambiguity function of S1(t) and S2(t)

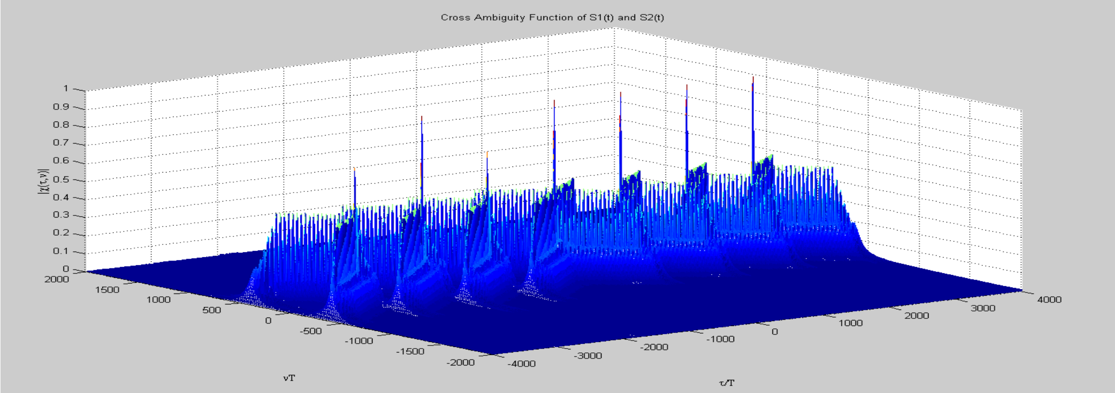

Fig 6: Cross Ambiguity function of S1(t) and S2(t)

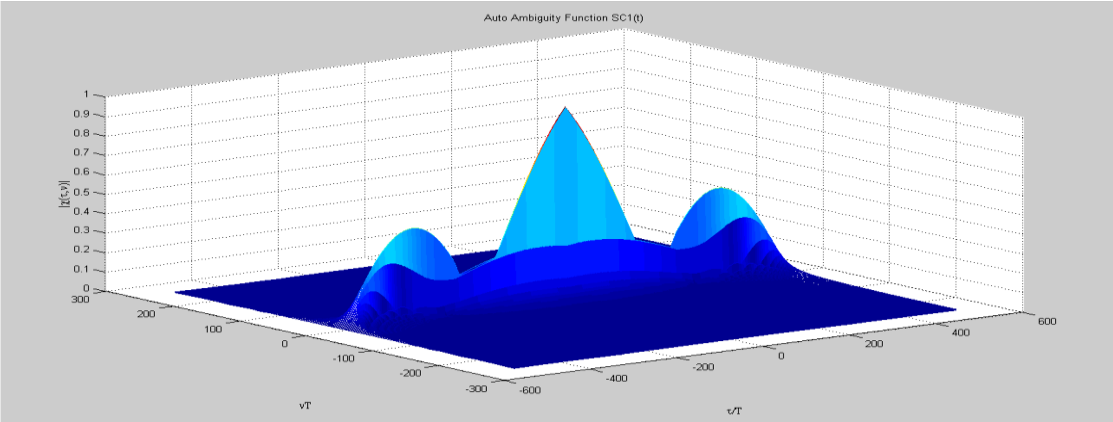

Fig 7: Auto ambiguity function of SC1(t)

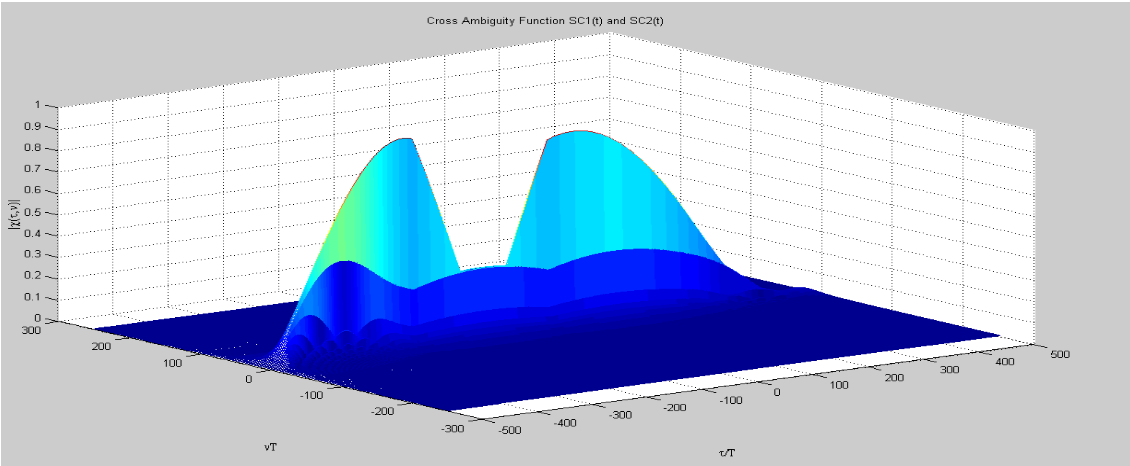

Fig 8: Cross ambiguity function of SC1(t) and SC2(t)

From the graphs above it is observed that the auto ambiguity function of s1(t) is similar to that of cross ambiguity function between s1(t) and s2(t). But it has more number of grating lobes because of which one cannot define the peak value. But after it s done with spread spectrum coding the grating lobes are reduced as observed in the graphs 7 and 8. Hence it can be concluded that this method significantly improves the orthogonality performance in case of closely separated targets.

Further, the CAF values for different code-lengths and different bandwidths are to be checked. And also keeping the code length constant and varying the bandwidth it must yield almost the same value of CAF. Since bandwidth is scarce resource, this property becomes an advantage.

IV. CONCLUSION

The combination of Spread Spectrum coding, OFDM and chirp signal is used in the way of achieving the desired objectives. The advantage of considering all these was mentioned in the earlier chapters.

The simulation results presented will give the following conclusions, The gold code proves to be the best among all the Direct Sequence Spread Spectrum codes by achieving low CAF value than all the other codes. OFDM chirp waveform scheme also provides good orthogonality performance but produces grating lobes. After DSSS coding there is significant reduction in the grating lobes and hence there is improvement in orthogonality performance. Compared to the existing system there is a significant reduction in the CAF values which still provide a scope for improvement. And another scope for improvement is to test the performance of the designed waveforms in the noisy environment

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