Cryptographic Systems Used in the Romanian Countries between the 15th - 19th Centuries

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ABSTRACT

Situated in the southeast of Europe, Romanian Countries had an intense diplomatic activity, even if this was not recorded accordingly in documents of the day. This activity, as well as others made use of cryptography and cryptographic systems. Considering the scarcity of books devoted to this topic, the present paper is a survey regarding some of the encryption systems used in the Romanian Countries in the 15th -19th centuries, and will include a comparative approach between these and other encryption systems used in Europe at the same time.

Keywords: cryptography, Cryptographic Systems, Romanian Countries

INTRODUCTION

Classical ciphers can often be broken using some statistical information about the plain text, which means *the frequency analysis of a letter in a text*. After the discovery of frequency analysis allegedly by the Arab mathematician Al-Kindi in the 9th century, most of these ciphers became breakable until the development of the *polyalphabetic ciphers*. It is most likely that these ciphers were introduced by Leon Battista Alberti around 1467 and they used different ciphers for various parts of a message.

The execution of Mary Queen of Scots showed the vulnerability of the mono-alphabetic substitution cipher and the cryptographers had to find a new, stronger cipher that could trick the cryptanalysts (Singh, 2005, 55). Leon Battista Alberti (1404-1472) (Williams et al., 2010), Johannes Trithemius (1462-1516) (Brand, 1981) and Giovanni Battista Porta (1535-1615) (Rienstra, 1963) brought important contributions and the new found cipher became known as the *Vigenère cipher* after the name of the French diplomat Blaise de Vigenère (1523-1596), who gave it the final form (Singh, 2005, 56; Reynard, 1996, 56; Bruen and Forcinito, 2005, 21). The latter published his work in *Traicté des chiffres, ou secretes manieres d'escrire* in 1586. That year, the cipher of Mary Queen of Scots had been broken. If Mary's secretary had read the Vigenere's treatise, he would have known about this new cipher. Although the Vigenere cipher was strong, it was rejected by the cipher secretaries since it was very hard to use at the time. During the following two centuries, this cipher was to remain largely neglected.

In the 17th century, the mono-alphabetic ciphers were used in several domains, but in diplomatic and military problems these ciphers were weak. The cryptanalysts of the time, who avoided the polyalphabetic ciphers due to their complexity, needed more secure ciphers and easier to use. One of the accepted ones was the *homophonic substitution cipher* in which each letter was replaced by a variety of substitutes whose number was proportional to the frequency of the letter (Singh, 2005, 60). The *homophonic substitution cipher* is a mono-alphabetic cipher.

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ISSN: 2186-8492, ISSN: 2186-8484 Print
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The Vigenère cipher is based on a single ordinary alphabet as in the case of Caesar cipher, and is easily solved after discovering its fixed period by means of the Kasiski test (Singh, 2005, 83; Klima and Sigmon, 2012, 96). This is not possible with the Alberti cipher, for example, which uses two mixed alphabets and the key varies continuously during encryption. Therefore, the discovery of a single letter does not permit further progress (Alberti, 1997).

Most of the encryption systems used in the Romanian Countries in the 15th -19th centuries had foreign origin: Byzantine-Slavic (as monastic cryptography), Austrian, Polish, etc. (as systems used in the diplomatic correspondence) (Mareş, 2007, 13).

As far as the terminology is concerned, the old cryptographic writing (monastic cryptography) is known as "filtă" in Wallachia and "hiltă" in Moldavia, while political and diplomatic encrypted texts used the term "ţifră" (synonymous with "cipher") (Maierean and Dulciu, 2010, 67).

Cryptography was used in all three Romanian Countries (Wallachia, Moldavia and Transylvania) in the princely chanceries, in monasteries and by private persons.

The monastic cryptology includes cryptograms used in public and private documents and cryptograms used in manuscripts, old books, correspondence, and mural notes. The monastic cryptography passed from the Greek Palaeography of Byzantium to the Palaeography of countries which used the Slavonic language. From here, it passed to the Romanian-Slavic Palaeography and finally it entered the Romanian-Cyrillic Palaeography. In the Romanian Countries, between the 15th century and the 19th century, we may find cryptograms in Romanian-Slavic texts and in Romanian-Cyrillic texts. Although the writers of cryptograms are monks, their encrypted texts do not directly preach about faith. Moreover, the cryptograms from manuscripts have no political allusions, but are rather like a spiritual game or like a riddle. However, the presence of encrypted texts in manuscripts made the interest, the curiosity and the mystery for some esoteric forms of the faith increase, indirectly providing an impetus for an increased interest in books and the writing itself (Vîrtosu, 1966, 262).

The cryptography for the diplomatic correspondence was used beginning with the 17th century, especially in the international relations of Wallachia and Moldavia. The first known encrypted message is from 1654 from the Prince of Moldavia Vasile Lupu (1632-1654) (Iorga, 1900). The oldest diplomatic cipher recorded in documents goes back to 1662 and was mentioned in a report written in the Romanian language by the Romanian representative of the Prince of Wallachia Grigore I Ghica (1660-1664; 1672-1674) in Istanbul (Mareş, 1986, 37-44). In the second half of the 17th century, the diplomatic ciphers were frequently used in the diplomatic correspondence of the Romanian Countries (Anton-Maria Del Chiaro, 1914, 141). After the instauration of the Phanariot rule (in 1711 in Moldavia and in 1716 in Wallachia), all information regarding the using of ciphers in the international relations of Wallachia and Moldavia was banned (Mareş, 2007, 20).

THE GREEK KEY

The most common encryption system used by Romanians in the 15th -19th century was *der griechische Schlussel* (The Greek Key) (Kalužniacki, 1883, 6). This encryption system has its origins in the Greek Palaeography and is based on the numerical values of the letters in the Greek alphabet. Letter-digits are arranged in ascending order in three distinct groups: units, tens and hundreds. Substitution is done by replacing the letters of each string with letters of the same string written in reverse. The Slavs adopted this encryption system and replaced the

Greek letters with letters with numerical value of the Cyrillic alphabet. The Romanians took the Greek Key system as it had been established by Slavs (Mareş, 2005, 359). This can be seen in the tables below:

Table 1

A(1)	B (2)	Г (3)	Д (4)	Є (5)	S (6)	З (7)	И (8)	Ѳ (9)
Ѳ (9)	И (8)	З (7)	S (6)	Є (5)	Д (4)	Г (3)	B (2)	A (1)

I (10)	K (20)	Л (30)	M (40)	H (50)	Ѯ (60)	O (70)	П (80)	Ч (90)
Ч(90)	П (80)	O (70)	Ѯ (60)	H (50)	M (40)	Л (30)	K (20)	I (10)

P(100)	C(200)	T(300)	У (400)	Ф(500)	X(600)	Ψ (700)	Ѿ(800)	Ц (900)
Ц(900)	Ѿ(800)	Ψ(700)	X (600)	Ф(500)	V(400)	T (300)	C(200)	P(100)

Sometimes, this encryption system includes changes in the phonetic value of some letter. These are only partially local changes lacking consistency in application, but they do not affect the whole encryption system (Vîrtosu, 1966, 271).

The simplicity of this encryption system explains its wide use in the Romanian encrypted texts compared to other secret writing systems such as, for instance, *der taraberische Schlussel* (Kalužniacki, 1883, 6; Mareş, 2005, 360).

If we apply the above principle to the Latin alphabet with the symbol "*" for the blank space, we obtain:

Table 2

A(1)	B(2)	C(3)	D(4)	E(5)	F(6)	G(7)	H(8)	I(9)
I(9)	H(8)	G(7)	F(6)	E(5)	D(4)	C(3)	B(2)	A(1)

J(10)	K(20)	L(30)	M(40)	N(50)	O(60)	P(70)	Q(80)	R(90)
R(90)	Q(80)	P(70)	O(60)	N(50)	M(40)	L(30)	K(20)	J(10)

S(100)	T(200)	U(300)	V(400)	W(500)	X(600)	Y(700)	Z(800)	*(900)
*(900)	Z(800)	Y(700)	X(600)	W(500)	V(400)	U(300)	T(200)	S(100)

From the above, the text "WE MEET IN CONSTANTA" will be encrypted WESOEEZSANSGMN*ZINZI.

The Greek Key is a mono-alphabetic cipher and was used either in its original form (see Table 1) or in various versions with small alterations, especially for those letters that remain unchanged. These new equivalences can be divided into two groups: the letters whose labels may be changed due to the type of encryption and the letters whose labels do not change according to this mode of encryption. We will mention some of them: Є replaced by И or

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vice versa, И replaced by Ф or vice versa, М replaced by Ч, С replaced by Ѿ or vice versa, etc. In total, there are twenty-eight such improvements reported in documents (Mareş, 2007, 40-43).

THE ARITHMETIC KEY

This cryptographic system used the values of labels associated with each of the Cyrillic letters and the way these labels can be written as the sum of several numbers can represent the labels for other letters. In the initial form, any Cyrillic letter can be reproduced by two or more Cyrillic letters written so that the sum of their labels is the value of the replaced letter. The *Arithmetic Key* is a kind of homophonic substitution cipher and is sometimes combined with the Greek Key.

For example, Ѯ (60) can be replaced by more combinations of letters: І (10)+ Н (50) or К (20)+ М (40) or Л (30)+ Л (30) or К (20)+ К (20)+ К (20) or І (10)+ Є (5)+ М (40)+Є (5), etc. We must remark that letter А=1 remains unchanged (Mareş, 2007, 57).

The Arithmetic Key was used especially by the Slavs (Kostić, 1913, 31-34; Iliev, 2012), the oldest record coming down from the 14th century, and rarely by the Greeks, whose earliest report comes from the early 12th century.

In the Romanian Countries, the first cryptograms which used this encryption system date from the early 16th century (in 1511) and are found in Moldova songbooks of the monk Evstatie from the Monastery of Putna (Constantinescu, 1967). We reproduce one of them below (Mareş, 2007, 57):

ААЪРРѪБМЛСРѪКЇАВЄАЧІГВААА = АА Ъ РР ѪБ МЛ СР Ѫ КЇ А ВЄ А ЧІ ГВ АА А =

= ВЪ СѪБѲТѪ ЛАЗАРЄВА (in the Saturday of Lazarus). We have АА =1+1=2=В, РР=100+100=200=С, МЛ=40+30=70= Ѳ, СР =200+100=300=Т, КЇ = 20+10=30=Л, ВЄ =2+5=7=З, ЧІ=90+10=100=Р, ГВ=3+2=5=Є.

The cryptograms written with the Arithmetic Key can be found in two princely acts from Wallachia; the first one was written at the village Greaca, Ilfov County and dated 16th of August 1532, while and the second one was written in Bucharest and was dated 5th of January 1549: in these, the copyists reproduced their name at the end of the manuscripts appealing to the various encryption systems. We will reproduce the second one, since it brought an improvement to the system, namely the substitution of letter А, whose label is 1, with the following group of letters ПѲ∧ПѲ∧=*half* + *half* = *an entire* (the abbreviation of the word половина = *half* in Russian):

УУКЄКЄПѲ∧ПѲ∧ = ѾНА

We have УУ=400+400=800=Ѿ, КЄКЄ=20+5+20+5=50= Н

By using the Arithmetic Key, we can encrypt the above message WE MEET IN CONSTANTA as following:

UT**C**B**W**V**L**J**D**A**C**B**S**S**W**V**F**C**M**J**W**V**B**A**M**K**M**J**O**M**S**S**J**U**M**J**S**S**J**

UT=300+200=W, CB=3+2=E, DA=4+1=E, WV=500+400=*, SS=100+100=T, LJ=40+10=M, FC=6+3=I,MJ=40+10=N, BA=2+1=C, MK=40+20=O,OM=60+40=S, JU=10+300=310=A and since any letter from Table 2 does not have such a label, we replace A by JU, the short from *Jumătate* (*half* in Romanian).

Therefore, if we separate the blue letters from the black letters, the encrypted text is

U	C	W	L	D	C	S	W	F	M	W	B	M	M	O	S	J	M	S	J

with the encryption key

T	B	V	J	A	B	S	V	C	J	V	A	K	J	M	S	U	J	S	U

We notice that we can use the same technique as in the Vigenère cipher to "add" the key to the plain text. Another remark is that we cannot use the frequency letter analysis in the text, since, for example, letters O and N have the same encryption letter M, and the same letter can be encrypted in a different way if we use other terms of the corresponding number of the label's letter. For example E can be encrypted with C or with D. In writing texts as the one above, this encryption system seems to be a kind of Vigenère cipher, a weak one, since the key is too long and it can be hard to remember (in the given example). This technique, "adding" the key to the plain text, appears to have been known in the Romanian Countries at least seventy-five years before the introduction of the Vigenère cipher and, as already mentioned, this key was known by the Greeks beginning with the 12th century.

In the Latin alphabet, by using the symbol " * " for the blank space and labeling with 27 with the same technique, we may encrypt the same text WE MEET IN CONSTANTA (see Table 3).

Table 3

1	2	3	4	5	6	7	8	9	10	11	12	13
A	B	C	D	E	F	G	H	I	J	K	L	M
14	15	16	17	18	19	20	21	22	23	24	25	26
N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Two labels will be used for letter A: 0 and 28, as in the Caesar Cipher. Therefore, we will obtain:

SDD**A**IM**L**A**A**DD**A**G**M**Z**A**E**D**M**A**N**M**B**A**K**D**M**A**F**M**S**A**X**D**M**A**G**M***A

We get the text SDILADGZEMNBKMFSXMG* encrypted with the key DAMA (red letters) and now it is much better, since the keyword is easier to keep in mind. Again, we can't use the frequency analysis of letters in the text, since, for example, letter E is encrypted with A or D while letters W and T are encrypted with S.

There are many other examples from other sources which related the use of this manner to encrypt letters in diplomacy or in some books, for example, in the so called *Gospel from London* (*Evangheliarul de la Londra*) copied by *Radu de la Măniceşti* (Radu from Măniceşti) in 1574, or in some ciphered inscriptions on the walls of the *Humor* Monastery situated in the North of Moldavia) (Balş, 1965). In these small cryptograms, the Cyrillic letter И was substituted by the Cyrillic block letters ДД. That means ДД=4+4=8= И (Mareş, 2005, 376-378).

Even if it used a technique as the one in the Vigenère cipher, this cipher is not a polyalphabetic one, but it can be considered a homophonic cipher, in which each letter is replaced by multiple versions. The number of these versions is directly proportional to the frequency of the letter in the considered alphabet. If a letter represents *x*% of all letters of the alphabet, then in order to represent that letter we will use *x* symbols (letters) of the respective

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ISSN: 2186-8492, ISSN: 2186-8484 Print
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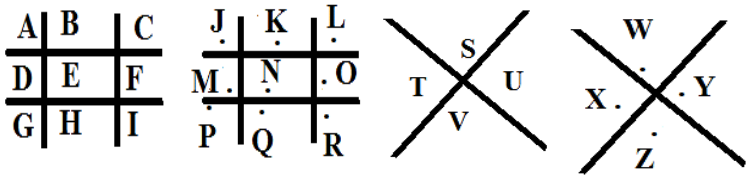
alphabet. This kind of cipher is harder to break than the monoalphabetic cipher and easier to use than the polyalphabetic one (Singh, 2005, 61). The homophonic cipher seems to have been used since 1467 in the Babington plot against Queen Elizabeth in a very interesting version, the Nomenclature. The Arithmetic Key, as seen above, did not use the frequency of a letter in the considered alphabet as an encryption system, but the decomposition of the corresponding label in sum of two or more terms. The most important homophonic cipher, called The Great Cipher, was used at the court of King Louis in the first half of the 17th century.

As an encryption technique, it is interesting to note that the Arithmetic Key is actually a combination between the homophonic cipher and the Vigenère cipher, but it is better than the former and weaker than the latter. What is interesting, and we want to emphasize this, again, is the fact that the Arithmetic Key uses the same technique as the Vigenère cipher. Therefore, the idea of "adding" keys had been known long before, and Vigenère was perhaps the first to make it public.

THE "PIGPEN" CIPHER

This kind of cipher uses symbols (conventional signs) instead of letters using the rules below:



The corresponding symbol of a letter is given by drawing the letter position, for example:

A=  , B=,….J= , K=,…,S=, W= , etc. This was used in the 18th and 19th centuries by Freemasons to encrypt their documents (Singh, 2005, 350).

In Romanian Countries, this cipher was used in diplomacy in a little different form with a different order of the letters and other figures: B=, I=, Z=, etc. For example, two acts of the Wallachian chancery issued on 16th of April 1687 and 5th December of 1687 and addressed to the Emperor Leopold I (1640-1705) were fully encrypted with this method. These documents are stored in the Archive of the Ministry of Interior in Vienna, which keeps the transcription made at that moment by the imperial chancellor who possessed the key of the cipher. At the end of these diplomatic two acts, the signature of Prince Şerban Cantacuzino's (in Latin: *Serbanus Cantacuzene*) is also encrypted with this method (Mareş, 2007, 114; Maierean and Dulciu, 2010, 94-95). Şerban Cantacuzino (1640–1688) was the Prince of Wallachia between 1678 and 1688 and took part in the Ottoman campaign, which ended in their defeat in the Battle of Vienna (Hitchins, 2014, 44-45). After his death in mysterious circumstances, he was followed by his nephew Constantin Brâncoveanu (1688-1714) on the Wallachian throne (Giurescu and Nestorescu, 1981, 175-176). Constantin Brâncoveanu's secretary, Anton Maria del Chiaro, was the first Romanian who established a Masonic Lodge in Galaţi (Moldavia) in 1734, called *Loggia di Galazzi* (Russell and Cohn, 2012).

This procedure, which used signs, isn't a Romanian invention. A similar cipher, with a decryption key, was found in the second half of the 17th century in an isolated paper preserved in the library of the Moscow Patriarchate or was used by the Freemasons at the beginning of the 19th century.

The decoding key of such a cipher was established following an unknown criterion. The encoding used by the Wallachians in 1687 was undoubtedly set in the Imperial Chancery, since the Austrians were recognized during that period for their successes obtained in the decryption of encoded texts (Mareş, 2007, 116).

It is important to note that a version of the above mentioned cipher, probably arising from the French Freemasonic lodges, was used in the Romanian Revolutionaries Correspondence during the Revolution of 1848 (Maierean and Dulciu, 2010, 116-119).

THE MIXED CIPHERS

The mixed ciphers (or combined ciphers), widely used in diplomacy, combined the various encryption systems used at that time, by either substituting only a part of the Cyrillic alphabet (the so called *Cyrillic cipher*) (Mareş, 2007, 99) or by using different alphabets (Cyrillic, Latin and Greek) together with some special signs and numbers. This kind of cryptographic system is indicated in a report sent from Constantinople in 1682 to Prince Şerban Cantacuzino. For example, α was encrypted with δ; γ with H; m with g; ζ with ⌒, χ with ⌒, etc.

Another cipher was used in a letter written in Latin by Constantin Cantacuzino in Târgovişte (Wallachia) and addressed to Francis Rákóczy, Prince of Transylvania, on 14 June 1708. This cipher was: A=o, B=2, C = ш, D= з, E=6, F=d, G= ┐, H =♀, I=e, L= h or m, M=ε, N=δ, O=5, P=κ, Q=y, R=ρ, S=g, T=Б, U=+, V=T, X= Ц. It is important to mention in this cipher the encryption of the letter X with Ц. It also used three special symbols, namely ♀, ┐, + and the numbers 2, 3, 5, 6. Since the Cyrillic letter Ц is specific to the Romanian and Serbian Cyrillic alphabet, this allows us to conclude that this cipher is a Romanian cryptographic creation (Mareş, 2007, 94).

Another cipher was the so called *Digit Encryption System* used for the Greek alphabet, in which the letters were encrypted using the corresponding labels in the Greek alphabet and replaced them with the corresponding Arab letters, as we can see in the following: α=1, β=2, γ=3, δ=4, ε=5, ς=6, ζ=7, η=8, θ=9, ι=10, κ=20, λ=30, μ=40, ν=50, ξ=60, ο=70, π=80, ϛ=90, ρ=100, σ=200,τ=300, υ=400, φ=500, χ=600, ψ=700, ω=800 (Mareş, 2007, 94). This cipher was used by the Prince of Moldavia Dimitrie Cantemir (Nelson, 1955) in his book *Istoria ieroglifică*, in which he wrote his name coded on the title page, as you can in the Figure 1:

4 8 40 8 300 100 10 400 20 1 50 300 5 40 8 100 = Δ η μ η τ ρ ι υ Κ α ν τ ε μ η ρ (Mareş, 2007, 94-95).

Figure 1

The polyalphabetic ciphers use different coded alphabets and change these between them during the encryption process (Singh, 2005, 55). As we have already seen, it appears that Alberti was the first to have done this. What we notice is that the same alphabet, the Latin one, was used in the case of Alberti, in which occasionally the order of the letters was changed and, automatically, from that moment the codification of letters was different than before. Etymologically speaking, *polyalphabetic* means the use of *more alphabets*. From this point of view, the ciphers used by Şerban Cantacuzino, Constantin Cantacuzino or Dimitrie

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Cantemir described in this section can be considered "polyalphabetic ciphers" even if they are monoalphabetic, as known from classifications, since three distinct alphabets are used.

CONCLUSION

Those who encryption systems used outside diplomatic purposes were usually employed by people with no special training like monks, deacons, priests, painters, carvers in stone. Many of them were convinced that such methods could gain them some superiority, compared to their fellows who were not prepared to initiate these methods. They used these cryptosystems more as a private game between them and the others. The scribes, painters and carvers used these cryptosystems in order to put their names at the end (coded, in order not to offend the master), both as a reward for their work, and as a reward (sometimes the only one!) for the hard work demanded in order to acquire knowledge in reading, writing and other skills, since these were not available to common people at the time.

In general, the encryption systems are based on a simple substitution, but they were encryptions corresponding to the Arithmetic Key which could successfully join the homophonic or the polyalphabetic ciphers and which could be used much earlier than the date when these two systems were created, advertised and used.

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