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The blasts' effect in Direct Systems Spread Spectrum Communications

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Abstract

In the domain of electronic warfare, jamming is an eavesdropping application. Spread Spectrum systems are RF communications systems, in which spread the information bearing digital signal across a broad bandwidth by injecting a higher-frequency signal. Spreading the energy of a bounded energy data signal across a very wide bandwidth causes the energy present at any particular frequency or small frequency band to be insignificant, which makes it transparent, but also vulnerable. In the environment where blasts are occurring that can be modeled as thermal noise at that frequency, DSS's energy spreading can be affected because of its sensitivity in the environmental reflections. In this context, this paper presents an innovative approach about the effects of fire blast effects in the neighboring DSS communications. This work includes a simulation of the jamming effects and compares the effect of jamming technique on the performance of a DSS signal with those available in the literature. The results of this simulation will be used to extract the maximum sensitivity of receivers and the maximum error rate by which the DSS communications can be implemented.

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1 Introduction

1.1 The problem

Spread Spectrum systems are RF communications systems, in which spread the information bearing digital signal across a broad bandwidth by injecting a higher-frequency signal. Spreading the energy of a bounded energy data signal across a very wide bandwidth causes the energy presence at any particular frequency or small frequency band to be insignificant, which makes it transparent, but also vulnerable. In the environment where blasts are occurring that can be modeled as noise at that frequency, DSS's energy spreading can be affected because of its sensitivity in the environmental reflections. This paper presents a study method about the effects of artillery's barrel blast effects in the DSS communications.

This work includes a simulation of the blast's effects and compares the effects on the performance of a DSSS signal with those available in the literature. The results of this simulation will be used to extract the maximum sensitivity of receivers and the maximum error rate by which the DSS communications can be implemented.

1.2 The researching objectives

The main researching objective of this work is to define if the artillery's blasts affect DSS communication used in the area. Secondary objectives that guided this work are the following:

1. Examine and study the principles of the electromagnetic pulses
2. Study the nature, the classifications of the EMP
3. Examine and study the DSS systems principles
4. Mark the DSS communications vulnerabilities
5. Study and remark the artillery blast's effect into the electromagnetic spectrum
6. Calculate by using literature sources the actual effects of the blasts into the DSS communications.

1.3 Methodology

In order to study the main researching objective, it was found useful to follow the method above:

a. Decide if blast can be defined as of a lower energy EMP incident.
b. Select the appropriate EMP type (e.g. lighting).
c. Study LEMP's effects as an EMI problem.
d. Design a simplified DSS communication scheme.
e. Study the DSS communication strength to EMI.

In order to answer to the aforementioned research objectives, the following route was used:

a. we examined and studied the principles of the electromagnetic pulses as also as the DSS systems principles.
b. we marked the DSS communications vulnerabilities.
c. we studied and remarked the artillery blast's effect into the electromagnetic spectrum.
d. we, finally, tried to propose a way to calculate the actual effects of the blasts into the DSS communications by using literature sources.

This work is organized in 3 main parts. In the first part, it is considered to be important to have a briefly presentation of the fundamentals of EMP. Secondly, a brief presentation of the DSS systems' properties, is consider to be necessary and the blasts’ effects analysis on EM spectrum based on the existing literature follow. In the second part we define the problem, we mark the assumptions and the restrictions been made and we present the analysis of the problem. In the final one, we present our conclusions as also as our proposals for future research.

2 Theory Background

2.1 EM theory principles - Literature Review

Electromagnetism is the combined effect of electric and magnetic fields [2], [3]. The fundamental equations of electromagnetic theory were established by James Clerk Maxwell in 1873 [4], [5], [6]. Propagation of an EM wave may be regarded as a means of transferring energy or information from one point (a transmitter) to another (a receiver). EM wave propagation is achieved through guided structures such as transmission lines and waveguides or through space [7], [8], [9], [10].

2.1.1 Antenna’s areas

In radio systems, around an antenna there are 3 areas-fields with different emission characteristics. These areas depend on the antenna’s characteristics as also on the wavelength of the emitted signal. These regions are the following [12], [13], [14]:

- Near field: The near field is considered to exist in the area from antennas centre to the distant R_1, In this area the field appears to be without ‘work’; that means that there is no electromagnetic energy radiation, although there is energy around.
- Fresnel Field: The Fresnel region extending from the region after the end of near field up to the distance R_2 This field appears to radiate the

transverse coordinates obtaining radially dependency. In the case of an antenna with small dimensions compared with the wavelength, Fresnel field does not exist.

- Far field: This area starts from the end of the Fresnel and ends theoretically to the infinity. It has the characteristic of the independence of the electric field from the radial distance (R_3).

3.2 EMP and its transformation as EMI

3.2.1 EMP

The electromagnetic pulse according to [15] is defined: *"An Electromagnetic pulse is a burst of electromagnetic radiation that results from an explosion or a suddenly fluctuating magnetic field. The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges. EMP is a broadband, high-intensity, short duration burst of EM energy."*

EMP produced as a side effect of a nuclear detonation, but also of non-nuclear sources, such as electromagnetic bombs, or E-bombs. [16] It is appropriate to mention that EMP has no known effect on living organisms, but can have various kinds of effects to electrical and electronic equipment. Because of its shortness has the ability to be spread over a range of frequencies. Typically contains energy at many frequencies from DC (zero Hz) to some upper limit depending on the source [17]. EMP does not distinguish between military and civilian systems. Unhardened systems, such as commercial power grids, telecommunications networks, and computing systems, remain vulnerable to widespread outages and upsets due to HEMP. [21]

Different types of EMP arise from the nature and man-made. In general we can categorize it in Nuclear Electromagnetic Pulse (NEMP) and in Lightning

Electromagnetic Pulse (LEMP). Both of them have the consequence on communications to produce Electromagnetic Interference (EMI).

3.2.2 EMI

The EMI according to [18], [19] is defined: *"EMI is disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source."*

In essence, Electromagnetic interference is defined to exist when undesirable voltage or currents are present to influence adversely the performance of an electronic circuit or system. In general, any unwanted electromagnetic signal or disturbance is often referred to as noise. So may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data [19], [20]. The source may be any object, artificial or natural, that carries rapidly changing electrical currents. In our research we are going to focus on EMI from an electrostatic discharge of a blast.

3.2.3 EMC

The Electromagnetic Compatibility according to [15], [19], [22] is defined: *"EMC is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment."*

EMC ensures the correct operation, in the same electromagnetic environment, of different equipment items which use or respond to electromagnetic phenomena, and the avoidance of any interference effects. Another way of saying this is that EMC is the control of EMI so that unwanted effects are prevented.

3.2.4 EMI from Electrostatic discharge

3.2.4.1 Lightning incidence

Lightning can affect the equipment in two ways [23]. The obvious way is by direct impact where the lightning channel connected to the system at some important point and leaves from elsewhere to complete the evacuation route in the ground. Lightning can also produce indirect effects of electromagnetic fields emitted by the rapidly changing trends and patterns in the lightning channel. The spectrum of a lightning pulse contains less energy in HF and VHF from a NEMP, as can be seen in Figure 3. The majority of the lightning pulse energy is limited to VLF. [23]

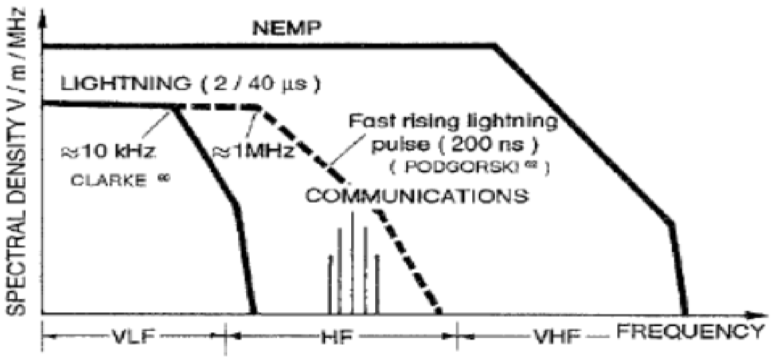


Figure 3: Compare of RF spectrum NEMP and Lightning (source: [24])

The Electromagnetism produced by the lightning channel at some distance can be calculated by considering the channel as an antenna where the current distribution in time and space varies. This current needs to be known only to calculate the vector potential, and then the scalar potential calculated by the Lorentz index. With both potentials known, the EM field can be calculated. The discharges from the cloud to the ground not affect the equipment directly is obviously more common than those affecting him. They can produce tensions radiated

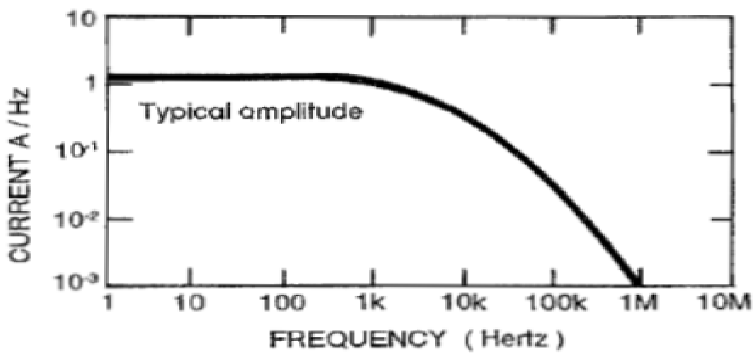


Figure 4: Typical spectrum density of lightning (source: [24])

electromagnetic fields of 6kV / m at a distance of 1 km from the channel of lightning. The measured spectrum produced by a standard evacuation can be seen in Figure 4. Note that this confirms that the lightning contains less high frequency energy from a hypertension NEMP. [23]

3.2.4.2 LEMP and its Characteristics

The LEMP according to [25] is defined: *"LEMP is the electromagnetic radiation associated with a lightning discharge. The resulting electric and magnetic fields can be coupled to electrical or electronic systems to produce damaging currents and surges."*

According to [26], the standard description of discharge of lightning is:

- Average rise time = 2 μs (range of values = 1-10 μs)
- Average duration = 40 μs (range of values = 20-200 μs)
- Average peak current = 20kA (range of values ≦ 150kA)
- Frequency of maximum radiation = 10kHz

3.2.4.3 Discharge of lightning

The ambient electromagnetic noise caused by electrical discharges in the atmosphere. [27]This can be either a local or wide area phenomenon. Strong ambient noise sources are lightning and electrostatic discharge. The lightning occurs as a result of electric discharge to the atmosphere from a cloud-bearing load. Clouds gather loads of atmosphere. [27] As a result of charge accumulation, clouds acquire sufficiently high potential relative to ground. When the field intensity in a charged cloud exceeds the level of collapse, the result will be an

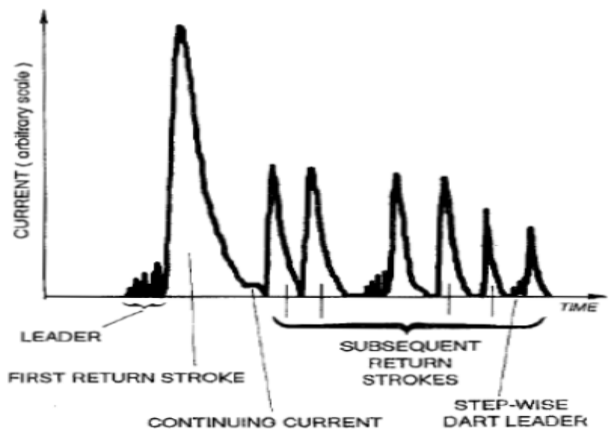


Figure 5: Graphical Representation of components of Lightning (source: [24])

electrical discharge. This discharge is a cloud on the ground, and a cloud to another. The discharge of a natural lightning event has proven to be a complex phenomenon that creates a number of components, as shown in Figure 5. The entire event can last for about a second and usually perceived as lightning. [23]

3.3 DSS systems principles - Literature review

Direct-sequence modulation entails the direct addition of a high-rate spreading sequence with a lower-rate data sequence, resulting in a transmitted signal with a relatively wide bandwidth. The removal of the spreading sequence in the receiver causes a contraction of the bandwidth that can be exploited by appropriate filtering to remove a large portion of the interference. [32].

Direct-sequence spread-spectrum transmissions multiply the data being transmitted by a "noise" signal. A direct-sequence signal is a spread-spectrum signal generated by the direct mixing of the data with a spreading waveform before the final carrier modulation. Ideally, a direct-sequence signal with BPSK or differential PSK (DPSK) data modulation can be represented by [28]:

$$s(t) = A\, d(t)\, p(t)\, cos(2\pi fc\ t + \theta)$$

where A is the signal amplitude, d(t) is the data modulation, p(t) is the spreading waveform, fc is the carrier frequency, and is the phase at t = 0. The data modulation is a sequence of nonoverlapping rectangular pulses of duration Ts, each of which has amplitude$d_i = +1$ if the associated data symbol is a 1 and $d_i = -1$ if it is a 0. To provide message privacy, data symbols and chips, which are represented by digital sequences of 0's and 1's, are synchronized by the same clock and then modulo-2 added in the transmitter. The adder output is converted according to 0 → -1 and 1 → +1 before the chip and carrier modulations. Assuming that chip and symbol synchronization has been established, the received signal passes through the wideband filter and is multiplied by asynchronized local replica of p (t). The multiplication yields the despread signal at the input of the PSK demodulator. Since the despread signal is a PSK signal, a standard coherent demodulator extracts the data symbols. [32]

Multiplication of the received signal by the spreading waveform, which is called despreading, produces the spectra of Figure 10 at the demodulator input.

Since its spectrum is unchanged by the despreading, white Gaussian noise is not suppressed by a direct-sequence system.

Now consider transmission by means of D equiprobable and equienergy orthogonal signals embedded in an n-dimensional space and a jammer, which energy is added to the signal with the inten to disrupt communications. Assume that the jammer's signal is independent of the desired signal. One of the jammer's objectives is to devise a strategy for selecting the components J_k^2 of his fixed total energy $E_J$so as to minimize the postprocessing signal-to-noise ratio (SNR) at the receiver.

So the received signal [28]

$$r(t) = S_i(t) + J(t)$$

A measure of performance is the signal-to-noise ratio defined as [28]

$$SNR = \frac{E^2(U)}{var(U)} = \frac{E_s}{E_J} * \frac{n}{D}$$

We observe that the SNR may be increased by increasing n. This factor n/D is the processing gain and it is exactly equal to the ratio of the dimensionality of the possible signal space to the dimensions needed to actually transmit the signals.

For example, If $J(t) = \frac{\sqrt{E_J}}{T}$ $, 0 \leq t \leq T$, then the receiver output is

$$U = E_b + \sqrt{E_b E_f}\,\frac{1}{n}\sum_{i=1}^{n} X_i$$

where the $X_i^{'}s$ are independent identically distributed random variables with $P(X_i = +1) = P(X_i = -1) = \frac{1}{2}$. The Signal-to-noise Ratio (SNR) is

$$\frac{E^2(U)}{\mathrm{var}(U)} = \frac{E_b}{E_J} n$$

Spectral spreading provides protection against a broad-band jammer with a finite power P_J. Consider a system that transmits Ro bits/s designed to operate over a bandwidth B_{SS} Hz in white noise with power density η_0W/Hz.
For any bit rate R [28],

$$(\frac{E_b}{\eta_0})_{actual} = \frac{P_S}{\eta_0 R} = \frac{P_S}{P_N} * \frac{B_{SS}}{R}$$

where

$$P_S \triangleq E_b R = signalpower$$

$$P_N \triangleq \eta_0 B_{SS} = noisepower$$

In order to ease reader's understanding, a matlab simulation runs to present the transformation of a bits sequence to a DSS complex waveform. In this example, a bit sequence is generated. This is converted to unipolar form and modulated by a random PN sequence and the product is according to the BPSK scheme's frame. The power spectral density of the DSS signal is plotting. As reader can see the information signal power is spreaded to a wider part of spectrum.

3.4 Blast's Principles - Literature Review

Blast may refer to:

1. Explosion, a rapid increase in volume and release of energy in an extreme manner
2. Detonation, a type of combustion involving a supersonic exothermic front accelerating through a medium that eventually drives a shock front propagating directly in front of it. Detonations occur in both conventional solid and liquid explosives, as well as in reactive gases. [34]

Electromagnetic radiation from conventional explosives originates from several sources as seen in figure 10. Radiation is emitted from projectile travel in the launch tube, muzzle blast after projectile exit, discharge of electrostatic buildup on a projectile in flight, detonation at target, and impact of metallic fragments at target. The characteristics of radiation from each of these scenarios may be different. [33]

3.4.1 the connection between blasts and EMI

This work is based on the following remarks used to base a strong connection between blasts and communication interference.

In the first line there is the fact that the radiation is believed to be related to the production and separation of ionized particles and electrons caused by the heat of the explosion that generates plasma. This kind of radiation can readily be considered to modify the noise of the near environment. In our experiment, we are going to focus on the blast after projectile exit from an artillery range. According to [1], the detect ability of the radiation depends on the thermal noise, background radiation noise, and the noise inherent in the sensor and the data acquisition system. The thermal noise power is given by

$$S_{noise} = kT_{amb}\Delta f$$

in which $T_{amb}$is the absolute temperature of the circuits in K, here taken to be 300 K, andΔf is the frequency bandwidth of the signal in hertz. The calculated values of Δf and E are given in table 1, with the noise power calculated from the above equation.

Table 1: Radiation from recombination of detonation products (source: [1])

Detonation product	Ionization energy (e-V)	Ionization energy (J)	Frequency (Hz)	Wavelength (Å)
N_2	15.5	2.48×10^{-18}	3.73×10^{15}	800
CO_2	14.4	2.30×10^{-18}	4.0×10^{15}	750

Table 2 shows the average power received as close as 1m to the detonation. The electron, which is the most detectable particle, is 11 dB below the noise, even at 1m. Even if an explosive 10.000 times larger than the mortar is used, only the electron radiation is detectable above the noise at close distances. [1]

Table 2: Detectability of estimated radiation from shock wave (source: [1])

Particle	Calculated *E*-field (V/m)	Δf (Hz)	Noise power (W)	Calculated Average power at receiver (W)	Detectability (dB)
0.191 kg explosive (mortar)					
			At 1 m		
Electron	6×10^{-4}	1.6×10^{12}	6×10^{-9}	4.8×10^{-10}	–11
N_2 Ion	1×10^{-8}	9×10^{9}	3.7×10^{-11}	1.3×10^{-19}	–84
O_2 Ion	9×10^{-9}	8×10^{9}	3.3×10^{-11}	1.07×10^{-19}	–85

Moreover, because of the existence of EMP from the detonation, we probably have some effects at communications. According to [33], EM radiation has been detected from detonation of conventional explosives over the frequency range from 0.5 Hz to 2.0 GHz. In most cases, the detection distance has been within 200m of the explosive event. This corresponds to the induction zone for frequencies below 300 MHz; hence, the magnitude of the radiated field has not been established. We observe that we have the same bandwidth between the military communications and the effect of a blast. Then we are going to examine to extent of the effects for DSS communications.

4 The solution

4.1 Concept and ideas

As reader understood in part 2, this works makes some necessary, by its point of view, “useful transformations” of the blast radiation field to a low energy

LEMP concept in the area of DSS systems. The next diagram shows this transformation.

4.1.1 Restrictions and assumptions

The following restrictions and assumption were framed this work:

1. No real experiment was able to be made. The threshold values used were taken from the existing academic literature.
2. The blast is considered to be a very short and of lower power EMP.
3. This fact is similar to the lightings' one, even though, its power is remarkable lower.
4. A more generic approach of the problem gave the flexibility to examine it, more thoroughly.
5. It is considered that both blasts and antennas are at the same spot.
6. Due to the existing data taken from the literature review, the simulation is limited to the 1 meter distance from the blast spot.
7. The e/m field produced by the blast is considered to be isotropic.

4.2 The research

In order to study the blast's effects into DSS communications, the following logical method was applied:

1. A DSS communication scheme with 2 radios is defined.

2. This communication is under the affection of the AWGN channel.
3. In the first phase, simulation measurements are taken for the BER of each station for the communication being in the AWGN state.
4. In the second phase, the EMP is considered to add noise in the AWGN channel.
5. The DSS system is simulated again and measurements are recorded.
6. The results are compared to the system's thresholds
7. Useful conclusions are pointed out.
8. For the simulation process Matlab Simulink is used.

4.2.1 The communication scheme

The DSS systems were programmed in MATLAB's Simulink environment. Two different DSS stations were programmed. Their general architecture scheme is presented in the figure of Appendix A. As reader can see, the information signal to be transmitted comes through a unipolar to bipolar converter and is multiplexed with the PN DSS sequence. The new signal is converted to unipolar and is modulated to the transmitter's output to BPSK modulation scheme. The AWGN channel propagates the signal to the other side -to the other radio, where is processed by the opposite demodulation sequence to its estimated initial form. The received signal is multiplying by the initial and the differences are presented. These differences are used to calculate the BER, the errors and the symbols at each side.

The properties of the basic elements of the simulation procedure are given below:

1. A sequence of 1200 bits is randomly generated. This is considered to be the original signal.
2. Channel's bandwidth is 0.5 MHz
3. System can operate at 0.5 -2 MHz

4. Radio unit's antenna is dipole has maximum length 15 cm.

   The distances of antennas' areas in centimeters are presented to the next table.

Table 3: The system's antenna fields

	Wavelength/4 (cm)	NEAR FIELD (cm)	FRESNEL FIELD (cm)	FAR FIELD
maximum wavelength	15.00	5.99	120.00	upper to Fresnel area
minimum wavelength	3.75	2.38	30.00	upper to Fresnel area

The PN generator has the following properties:

1. Generator Polynomial [1 0 0 0 0 1 1]
2. Initial state [1 1 0 0 0 0]
3. Sample time : 1/32000

The properties of the AWGN channel are given below:

- <u>initial state of AWGN (with no EMP presence)</u>
  - Eb/No (db) =1
  - Number of bits per symbol=1
  - Input signal power (Watts) =1
  - Symbol Period =1/32000
- <u>state of AWGN with EMP presence</u>
  - Eb/No (db) = -1 (calculated by the data retrieved from the literature review and it is analyzed to the next paragraph)
  - Number of bits per symbol=1
  - Input signal power (Watts) =1
  - Symbol Period =1/32000

4.2.1.1 Estimating blast's EM noise level.

In order to calculate the noise level produced by an artillery blast the information presented in paragraph 3.5.1. The EMI noise energy by the detonation products according to Table 2 equals to N_1 for average duration to 40μs, thus it affects by adding noise N_1 equal to :

$$N_1=4,78*10^{-18}\text{ Joule }*4\ 10^{-6}\text{s} =20\ 10^{-24}\text{ Watt}$$

Tha EMI noise energy by the shock wave is equal to

$$N_2=6,07\ 10^{-9}\text{ Watt/Hz} .$$

For the DSS's bandwidth (0.5 MHz) the EMI noise energy by the shock is $N_3=6,07\ 10^{-9} *0.5e\ 10^{6}\text{Watt/Hz} =3.035\ 10^{-3}$ Watt at 1 meter distance of the blast's spot.

Thus, total blast's EMI level is the sum of the above noise levels

$$N_{total} = N_1 +N_3= 3.035\ 10^{-3}\text{ Watt at 1 meter of the blast's spot,}$$

Noise total =4.82 dBm for a time equal

4.2.2 The simulation

The simulation results of the no EMP phase are given in the following table.

Table 4: The results from the simulation with no blast existence.

Property	Station 1	Station 2
BER	0.0005	0.0006
Errors	5	6
Symbols	1e+04	1e+04
Communication Duration	312400 μsec	

The simulation results of the EMP phase are given in the following Table 5.

Table 5: The results with blast.

Property	Station 1	Station 2
BER	0.0136	0.0135
Errors	136	135
Symbols	1e+04	1e+04
Communication Duration	312400 μsec	
Blast duration	1000 μsec	

According to the information above, the following useful statements can be made.

1. The EMP presence adds into the AWGN channel noise capable to increase the system's BER about 27.9 times at the distance of 1 meter away from the point of blast. Thus, blast makes communication worst by adding a 4.7db noise effect in the distance of 1 meter, in the case that antenna and blast are at the same spot.
2. This conclusion definitely affects systems' reliability in the case antenna and blast are at the same spot.
3. This effect is calculated for the distance of 1 meter, which is according to table 4 in the Fresnel area of the selected antenna. This fact is a strong argument for the conclusion that blasts affect DSS communications
4. Beyond these simulations, in the real world, blast and antennas cannot be in the same spot. So, this fact is the solution key for the problem. DSS station and artillery's blasts must be in distances greater than 1 meter, distance that is a very logical one.

5 Discussion and conclusions

Many remarkable conclusions have come out by the theoretical and practical study. According to the following useful statements can be made.

1. By the theoretical study

a. The Electromagnetism produced by the lightning channel at some distance can be calculated by considering the channel as an antenna where the current distribution in time and space varies. This current needs to be known only to calculate the vector potential, and then the scalar potential calculated by the Lorentz index. With both potentials known, the EM field can be calculated. The discharges from the cloud to the ground not affect the equipment directly are obviously more common than those affecting him. They can produce tensions radiated electromagnetic fields of 6kV / m at a distance of 1 km from the channel of lightning.

b. Direct-sequence modulation entails the direct addition of a high-rate spreading sequence with a lower-rate data sequence, resulting in a transmitted signal with a relatively wide bandwidth. The removal of the spreading sequence in the receiver causes a contraction of the bandwidth that can be exploited by appropriate filtering to remove a large portion of the interference.

c. Blast's radiation is believed being related to the production and separation of ionized particles and electrons caused by the heat of the explosion that generates plasma. This kind of radiation can readily be considered to modify the noise of the near environment. Moreover, the detectability of the radiation depends on the thermal noise, background radiation noise, and the noise inherent in the sensor and the data acquisition system. Finally, because of the existence of EMP from the detonation, we probably have some effects at communications. According to [33], EM radiation has been detected from detonation of conventional explosives over the frequency range from 0.5 Hz to 2.0 GHz.

2. By the method applied we handled blasts as lightings. By these transformations, we concluded serious interference to DSS systems operation in the area. This transformation must be considered as a work tool used for our work. In real world, as far we concern, there is no other useful transformation can be used.

3. By the simulation of this work we can conclude the following:

a. Blast, behaving as LEMP, adds into the AWGN channel noise capable to increase the system's BER at the distance of 1 meter away from the blast's point. Thus blast makes communication worst adding a notable noise effect in the distance of 1 meter

b. This conclusion definitely shows a reduction to system's reliability.

c. This effect was calculated for the distance of 1 meter, which is according to table 4 in the Fresnel area of the selected antenna.

d. By the simulation results as far as the literature studied, there are not strong indications about blasts' interferences with the stations operating at distances greater than 1 meter.

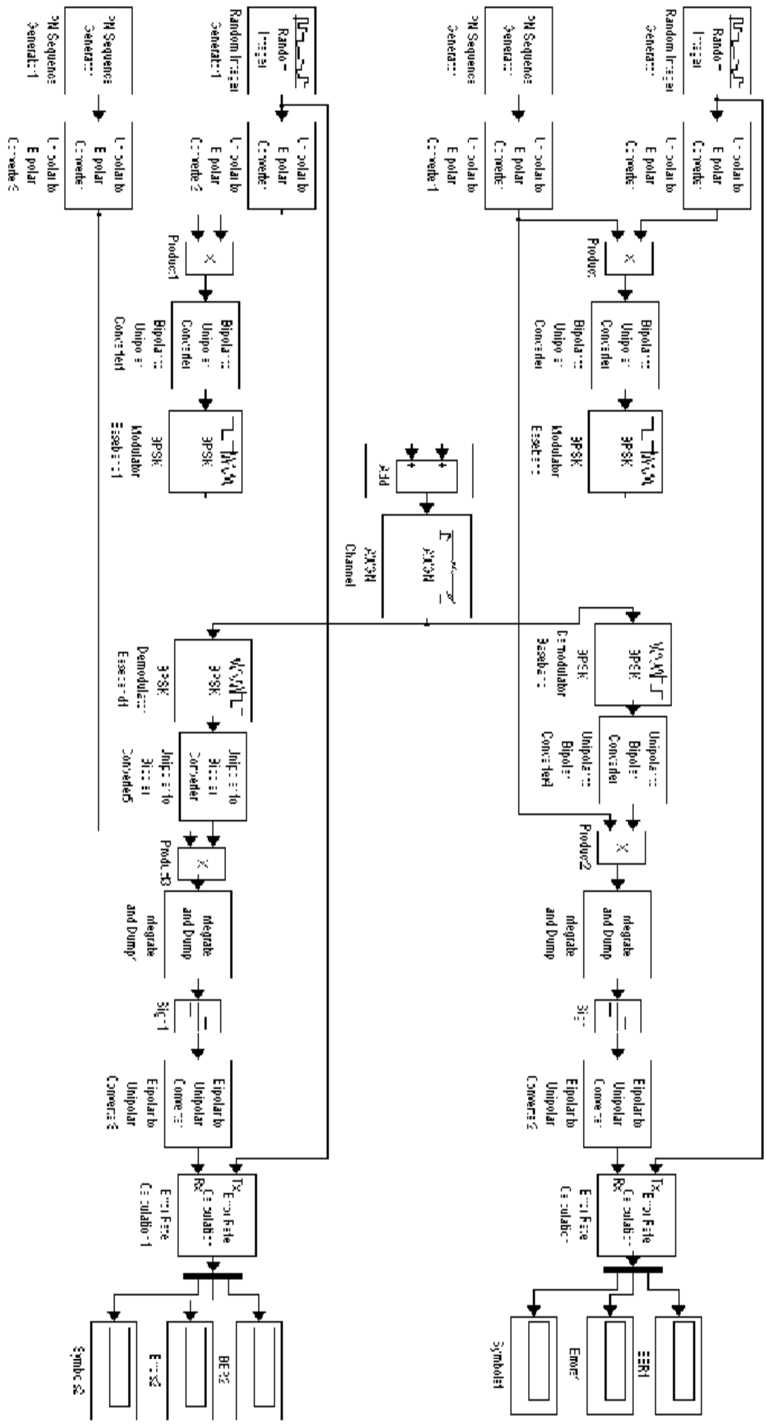
e. On the other hand our simulation took place with the assumption of the antennas and blast's point being at the same spot, which in real world cannot be done.

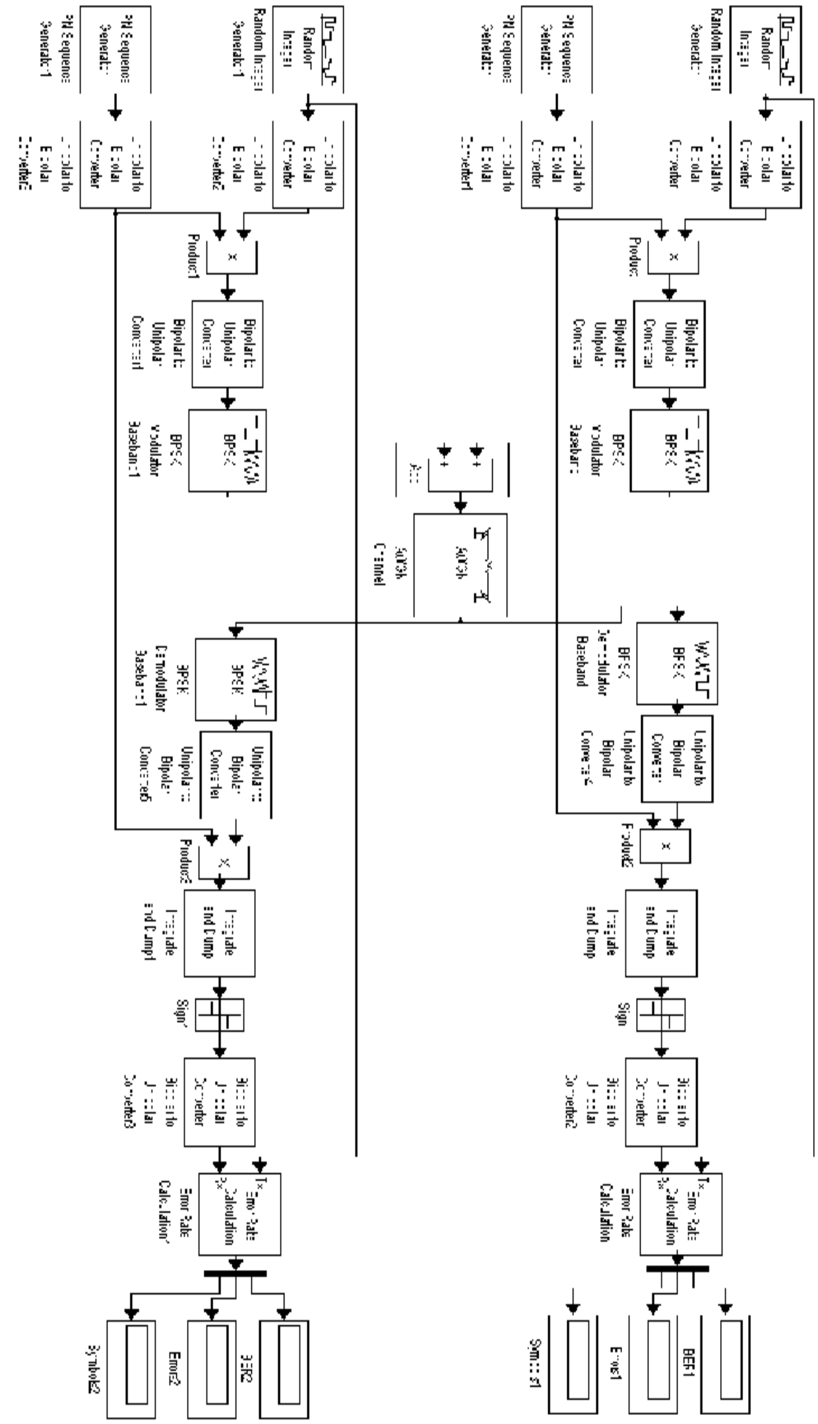
5.1 Future Research

As far it concerned the future research of the concept studied, a number of potential research directions are proposed:

1. Study of the real nature of the pulses produced by artillery's blasts.
2. Study of the e/m field format
3. Study of the way that artilleries barrel isolates or directs the e/m filed of the blast.
4. System performance with different types of DSS
5. Experimenting with different spread spectrum encoding parameters.
6. Use of techniques to enhance recovery of the jammed signal
7. Real - time implementation.
8. Investigate different signal schemes for the generation of the PN sequence.
9. Study of the blast effect at time of detonation at target

Appendix A





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