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# Applications of Simulation Modelling Method in Prevention of Jamming Attacks

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# ABSTRACT

- Background and method
- Aim
- Results and conclusion

# Background and Method

- In cybersecurity the method of simulation modelling has advantages for effective prevention.

# AIM

The aim of this paper is to contribute to development of techniques for cyber defense by a joint application of simulation modelling of a jamming type of DoS (Denial-of-Service) attacks using software Riverbed Modeler Academic Edition 17.5 and jamming antennas using CST Studio Suite 2021.

# Results and Conclusion

The results show that the proposed approach is suitable for determining the severity of cyberattacks due to the complementarity of selected products.

# I. Introduction

Simulation software

Jamming and anti-jamming antennas

A classification of horn antennas

# JAMMING AND ANTI-JAMMING ANTENNAS

- Horn antennas for jamming are:
  - *characterized by a capability to direct radio waves very accurate [1].*
  - *designed to cover a broad frequency spectrum as their applications work mainly at microwave frequencies, UHF (300 MHz to 3 GHz), although their range is wider (150 MHz to 15 GHz) [2].*
- „Anti-jamming uses massive planar antenna arrays“ [3]:
  - *are characterized by a low-cost and ultra-wide band.*

# Simulation Software

- Riverbed Modeler Academic Edition 17.5 - for studying the impact of a jamming attack on a communication network.
- CST Studio Suite 2021 - for simulation of jamming antennas.

# A Classification of Horn Antennas

- For ground platforms;
- For mobile platforms;
- For airborne platforms;
- For fixed platforms;
- Gain standards for calibration.

# CONTENT

| | |
|---|---|
| SECTION II | Presents the background and provides a literature review. |
| SECTION III | Emphasizes on the advantages of a jamming attack simulation using Riverbed Modeler Academic Edition 17.5. |
| SECTION IV | Represents the main concept of the study supported by a comparative analysis of the experimental results obtained from various simulations of cyberattacks on the model of a typical control centre of a management system. |
| SECTION V | It is devoted to the second part of the research related to analysis and simulation modelling of horn antennas which are applicable in jamming and includes a summary evaluation and analysis. |

# II. Related Work

A. A classification of main techniques for detection and prevention of jamming

B. Advanced jamming and anti-jamming techniques in wireless networks

# *A. A CLASSIFICATION OF MAIN TECHNIQUES FOR DETECTION AND PREVENTION OF JAMMING*

- Channel surfing [4]:
  - *can be realized by a specific spectral evasion by "legitimate wireless devices changing the channel that they are operation on".*
- Spatial retreat:
  - *a method based on a spatial evasion characterized by moving legitimate mobile devices away from the location of the DoS emitter [5].*

# *A. A CLASSIFICATION OF MAIN TECHNIQUES FOR DETECTION AND PREVENTION OF JAMMING*

- Randomized channel hoping over multiple channels:

  - *the scheme Quorum Rendezvous Channel Hopping (QRCH) allows nodes to hope over random channels without pre-key establishment, transmitting packets to many receivers at the same time and exchanging pending messages when meet in the limited time interval [6].*

# *A. A CLASSIFICATION OF MAIN TECHNIQUES FOR DETECTION AND PREVENTION OF JAMMING*

- Reactive jamming detection:
  - *„targeting packets that are already on the air "protect the attacker from disclosure [7].*
  - Hermes nodes:
  - *represent hybrid DSSS (Direct-sequence Spread Spectrum) and FHSS (Frequency-hopping Spread Spectrum schemes for prevention of attacks in sensor networks [9].*

# *A. A CLASSIFICATION OF MAIN TECHNIQUES FOR DETECTION AND PREVENTION OF JAMMING*

❑ Trigger control detection:

- *„detection of trigger nodes whose transmissions invoke the jammer nodes“.*
- It aims all target packets to be destroyed while the jamming is performed in the shortest possible time interval [8].

# B. Advanced jamming and anti-jamming techniques in wireless networks

- Prevention by “accurate detection of RF transmissions” and effective jamming, while a packet is still on the air [7].
- Using FHSS:
  - *it opposes fast-following jammers by 55 frequency channels and an average of 1 000 000 hops pers second.*
- Using DSSS:
  - *it is misleading the attacker to perceive the signals as white noise characterized by containing all frequencies and being broadband* [9].

# III. Advantages of Using Simulation Modelling of Cyberattacks for Network Security Analysis

Studying the impact of DoS attacks on control centres

A classification of jammers

# Studying the impact of DoS attacks on Control Centres

- Jamming attacks are a type of DoS attacks where the attacker aims to interrupt communication by transmitting a high-range signal.
- DoS jamming attack blocks the legitimate signals leading to a denial of service [12].

# A Classification of Jammers

- Pulsed jammer (a fixed, a mobile or a satellite node):
  - *this jamming is directed against airborne pulse-Doppler radar [13] that are used for "detection of moving targets" [14].*
- Single band jammer (a fixed, a mobile or a satellite node).
- Frequency-swept jammer (a fixed, a mobile or a satellite node):
  - *this type of jamming is expressed in a fast electronic sweeping of a narrow band of jamming signals in a wide frequency spectrum.*

# IV. A Comparative Analysis of the Results Obtained from Simulations of Cyberattacks

Cases and scenarios in the empirical study

Building simulation models in Riverbed Modeler

A. Summary evaluation and analysis

# Cases in the Empirical Study

| | |
|---|---|
| Case 1 | A reference model $M_{Ref}$ with a firewall. |
| Case 2 | $M_{Ref}$ with a firewall inserted under the impact of a DoS attack simulated by common cyber_effects (Fig. 1). |
| Case 3 | $M_{Ref}$ with a firewall inserted under the impact of a DoS jamming attack (Fig. 2) - the base frequency of the pulse jammer is set to 2401 MHz with 22 MHz bandwidth as in another study using the same simulation environment [16]. |
| Case 4 | $M_{Ref}$ without a firewall inserted under the impact of a DoS jamming attack. |

# Scenarios in the Empirical Study

| | |
|---|---|
| Number | Each of the cases is performed in 6 scenarios. |
| Input Parameters | Interarrival Time (T) of the packets in the range of 0.02 to 2 seconds starting from 2 seconds in Scenario 1 and ending with 0.02 seconds in Scenario 6 for $M_{Ref}$. |
| Output Parameters | End-to-End Time Delay ($T_D$) of the packets. |

# Simulation Models in Riverbed Modeler

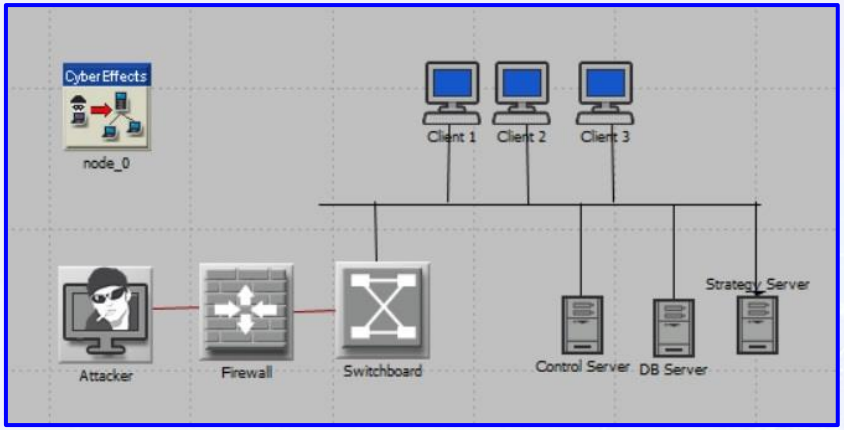



**Fig. 1. A reference model of the control centre $M_{Ref}$ under the impact of a standard DoS attack.**

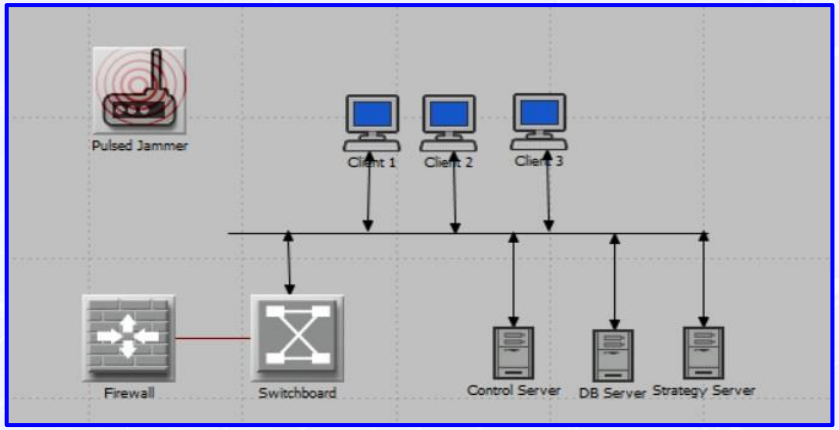



**Fig. 2. A reference model of the control centre $M_{Ref}$ under the impact of a DoS jamming attack.**

# Simulation Results

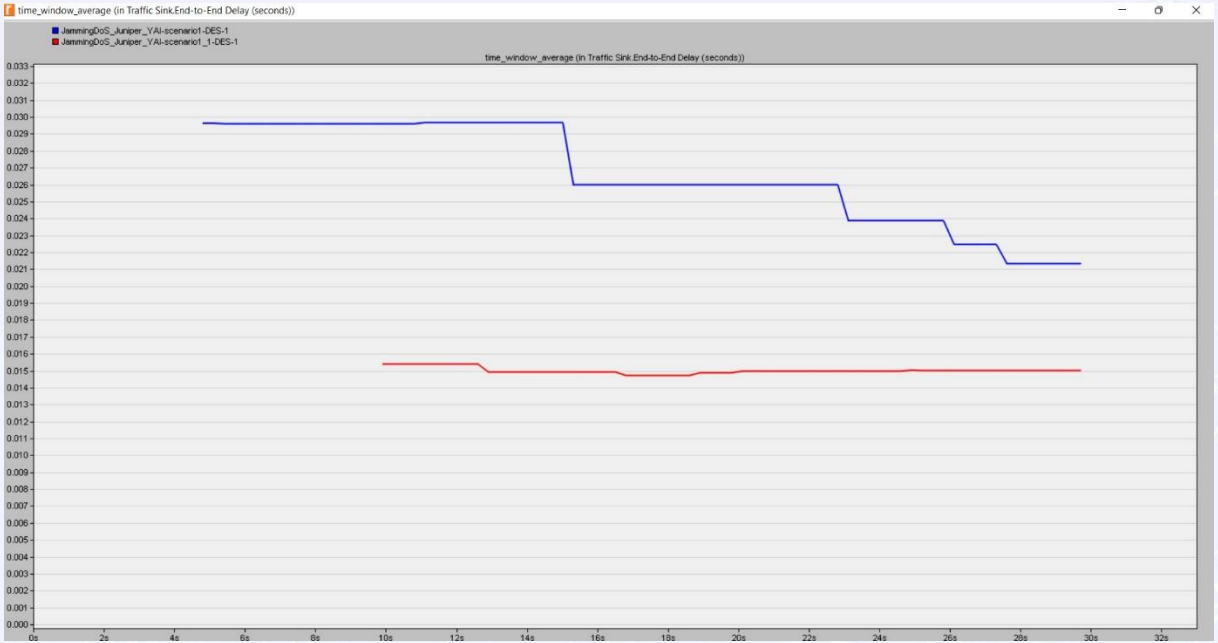



**Fig. 3. The comparative diagram of the time delay in Cases 1 and 2 (T = 2 [s]).**

# SIMULATION RESULTS

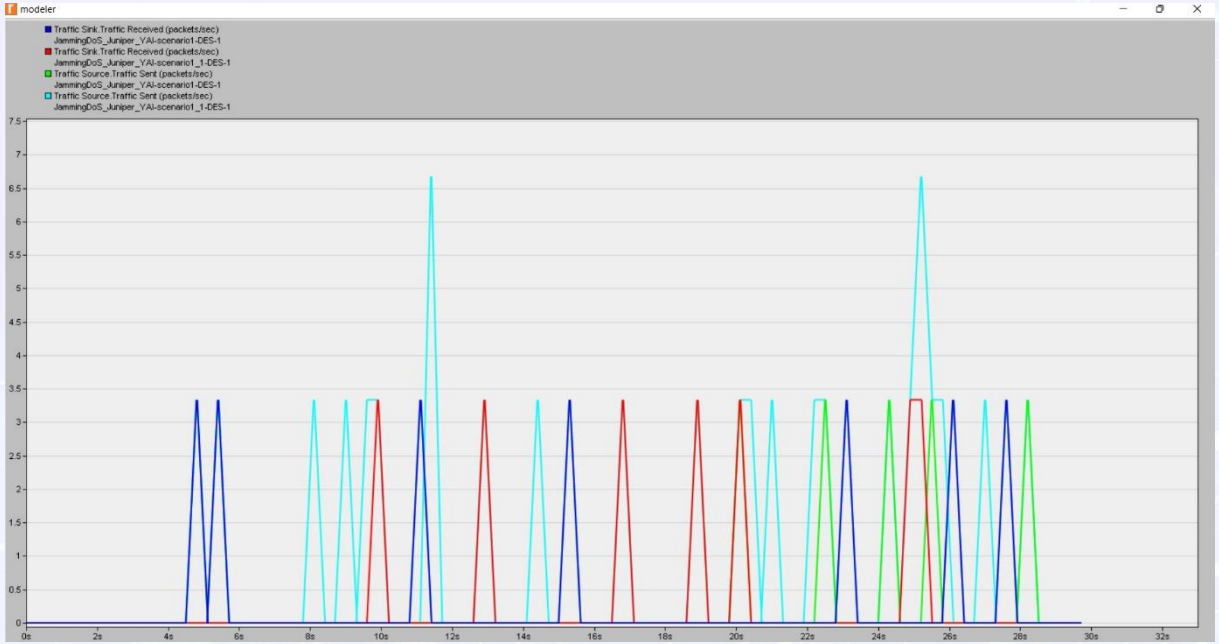



**Fig. 4. The comparative diagram of the packets sent and received per second in Cases 1 and 2 (T = 2 [s]).**

# SIMULATION RESULTS

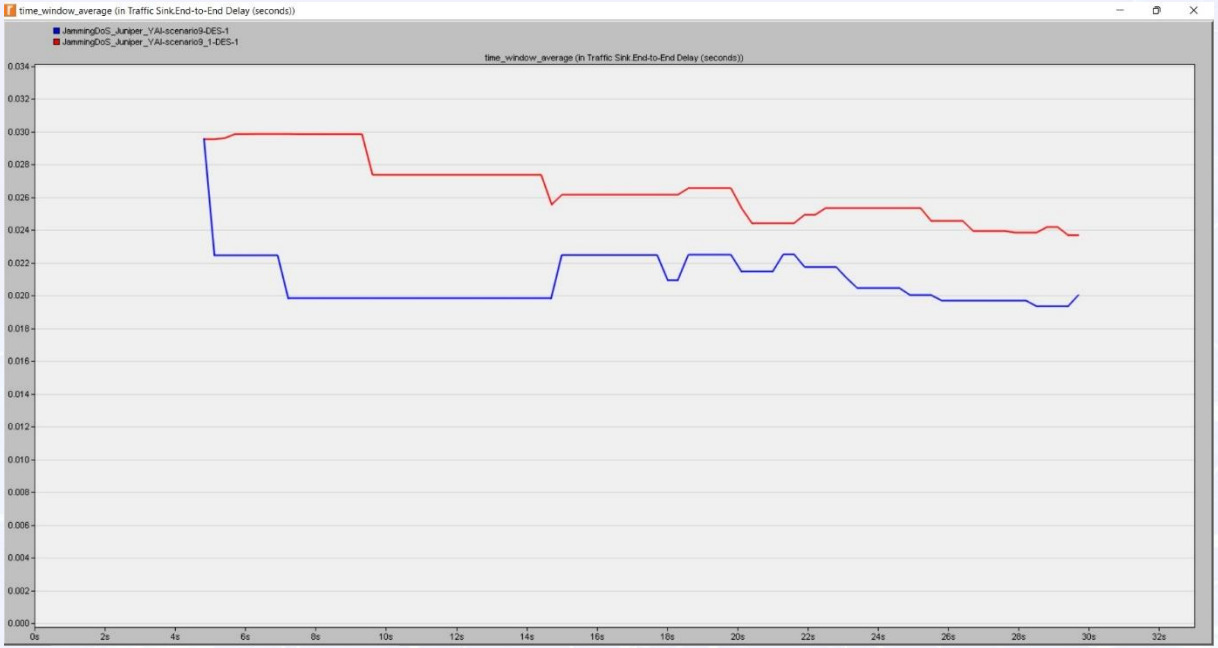



**Fig. 5. The comparative diagram of the time delay in Cases 3 and 4 (T = 1 [s]).**

# A. Summary Evaluation and Analysis

Cases 1 and 2

The conclusion from the comparative analysis of the results in the first two cases in two selected scenarios depending on $T_D$ is that the standard DoS simulated by *cyber_effects* has a stronger negative impact on the control centre, because the firewall does not completely prevent it (Fig. 3).

As the diagram in Fig. 4 shows twice as many packets were sent, as a result of the cyberattack which can be a signal for flooding and subsequent depletion of server computing power.

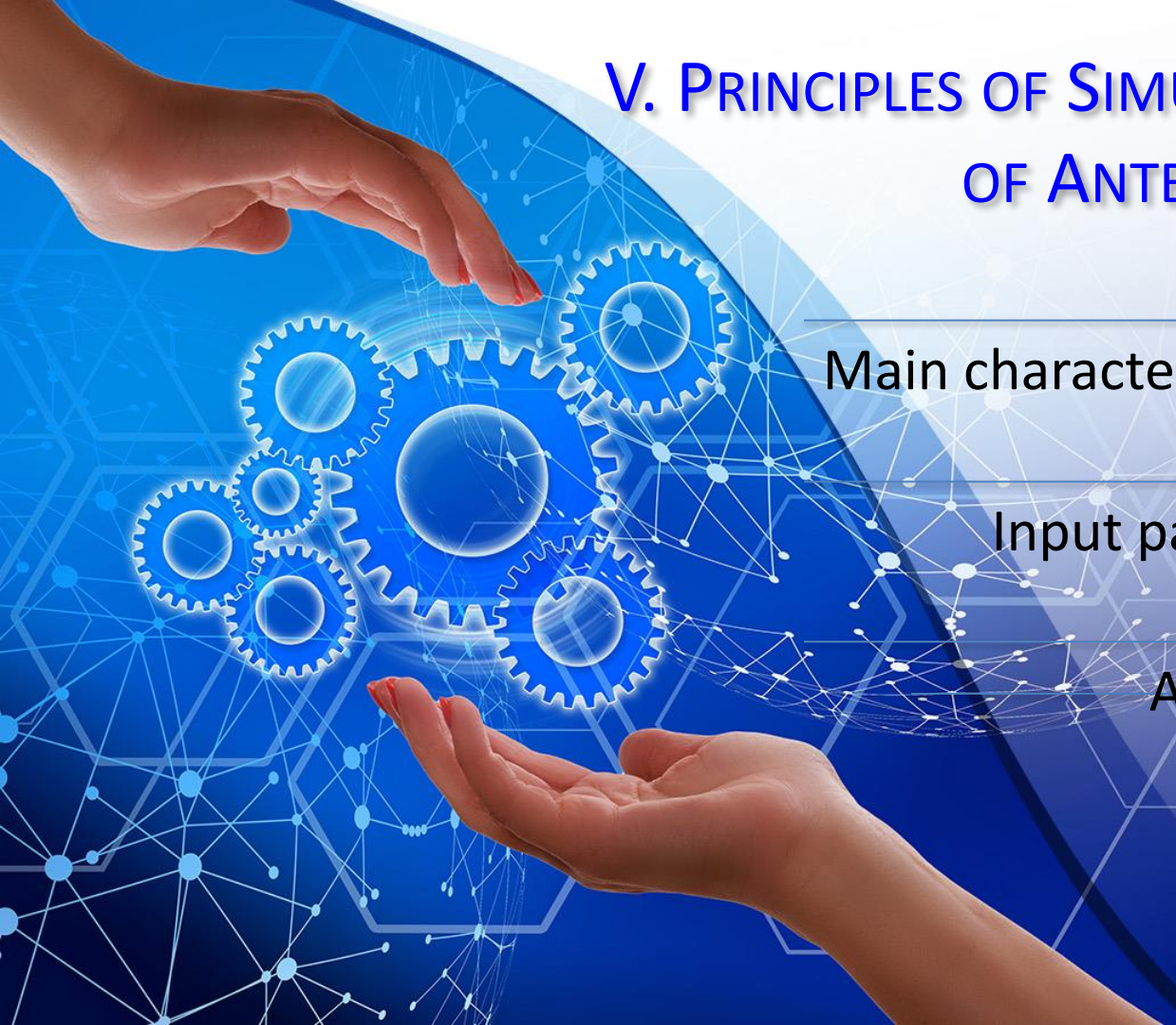
# A. Summary Evaluation and Analysis

**Cases 3 and 4**

The comparative diagram shows $T_D$ in two selected scenarios. In the first of them there is a firewall and no delay because of the jammer, but only due to the firewall (the blue line). In the second scenario no firewall is placed in the network and $T_D$ increases (the red line) – Fig. 5.

**Conclusion**

The simulation results obtained are a reason to assume that the standard DoS attack has a more negative impact compared to a DoS jamming attack in this software.



# V. Principles of Simulation Modelling of Antennas for Jamming and Anti-jamming

Main characteristics of a rectangular horn antenna

Input parameters for antenna modelling

A. Summary evaluation and analysis

# MAIN CHARACTERISTICS OF A RECTANGULAR HORN ANTENNA

- Aperture (A) - the physical area of the aperture.
  - *the emitting opening which have to be at least two times larger than the size of the waveguide.*

$$A_E = \sqrt{2\lambda L_E} \qquad A_H = \sqrt{3\lambda L_H}$$

- e – the efficiency with a value in the interval (0; 1).
- λ - the wavelength.
- $L_E$ and $L_H$ - the slant lengths of the side in the E- or H-field direction [17].

# MAIN CHARACTERISTICS OF A RECTANGULAR HORN ANTENNA

- Optimal gain (G) – if the source is isotropic then it is expressed as:

$$G = \frac{4\pi Ae}{\lambda^2}$$

- Direction (D) - the direction and gain of the antenna increase in direct proportion to the opening area [18].

$$D \approx 10log\frac{10A}{\lambda^2}$$

# INPUT PARAMETERS FOR ANTENNA MODELLING

| Input Parameters, [GHz] | Scenario 1 | Scenario 2 |
|---|---|---|
| **Frequency range** | 0-10 | 0-10 |
| **Farfield/RCS (Radar Cross Section)** | 2; 5; 9 | 4; 6; 8 |
| **Surface current (Transmission Line Matrix)** | 2; 5; 9 | 4; 6; 8 |
| **Electric/Magnetic Energy Density** | 2; 5; 9 | 4; 6; 8 |
| **E-field (Electric field)** | 5 | 9 |

# Simulation Models in CST Studio Suite 2021

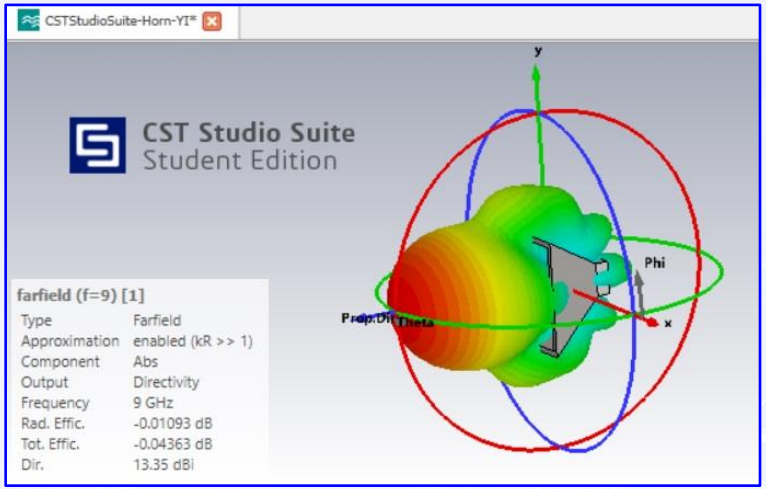



**Fig. 6. The simulation results at farfield (f=9).**

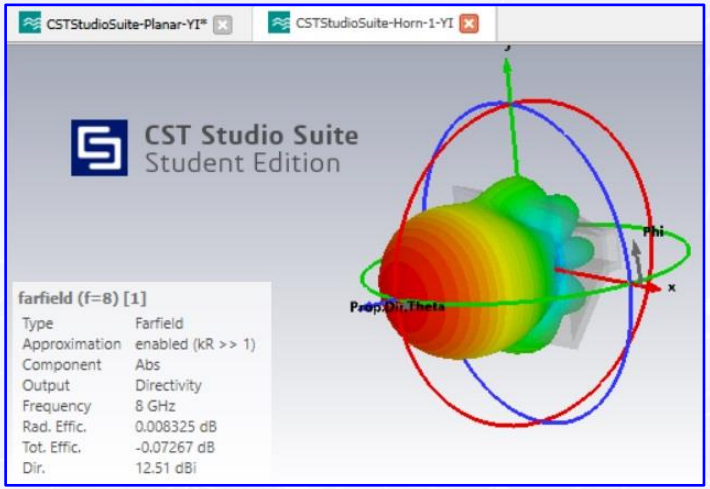



**Fig. 7. The simulation results at farfield (f=8).**

# A. Summary Evaluation and Analysis

| | |
|---|---|
| Output Parameters | They determine the level of effectiveness of a potential jamming. |
| | „Dir.“ is the amount of power that the horn antenna can send or receive in a particular direction. |
| | „Rad. Effic.“ (Radiation Efficency) is the ratio of the power emitted from the antenna to the input power supplied to the antenna excitation port. |
| | „Tot. Effic.” (Total Efficiency) is the ratio of the power emitted from the antenna to the power incident from the network. |
| Conclusion | The efficiency at farfield (f = 9 GHz) is 13.35 dBi. When the frequency is lower with 1 GHz the efficiency decreases to 12.51 dBi. |

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