Investigating Leakage from Spurious Emissions via Accidental Electric Antennas

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Abstract. *Ensuring the information security of electronic computing equipment is a critical task for technical protection complexes. A significant threat is posed by spurious electromagnetic emissions. While previous research focused on the magnetic field component's re-radiation, the channel formed by the electric field remains understudied. This report aims to build a quantitative model of this leakage channel, where the electric field from main technical equipment induces a signal in a conductor acting as an accidental antenna formed by auxiliary systems. The study covers induction, re-radiation, and their impact on the hazardous zone. The proposed quantitative approach shows that ignoring this channel can lead to an underestimation of the hazardous zone's radius by fifty percent or more. The results prove the necessity of a comprehensive analysis of both electromagnetic field components for an adequate threat assessment and the implementation of more effective security methods.*

Keywords: *information security; spurious electromagnetic emissions; technical information leakage channel; re-radiation; accidental antennas; electric field induction; controlled zone.*

I.INTRODUCTION

Ensuring the comprehensive technical information security (TIS) at electronic computing equipment (ECE) facilities is a fundamental task of modern information security [1, 2]. A significant threat to restricted information is posed by technical information leakage channels (TILC). Among these, channels formed by spurious electromagnetic emissions (SEME) are particularly dangerous because they do not require physical access to the equipment and can be intercepted remotely, often without the owner's knowledge [1]. These emissions can propagate far beyond the established controlled zone (CZ), creating a significant vulnerability.

Scientific works and regulatory documents in the field of TIS have paid considerable attention to modeling direct SEME channels [3]. Some studies, in particular, provide a detailed model for the TILC formed by the re-radiation of the magnetic field component from the main technical equipment (MTE) onto auxiliary technical equipment and systems (ATES) [4]. However, this approach covers only one of the possible physical mechanisms of interaction. The electromagnetic field in the near-field (Zone 1), where auxiliary equipment is typically located, is complex, possessing both strong magnetic and electric components whose relationship is not as simple as in the far-field [5]. Neglecting the electric component and its interaction with the surrounding environment creates a "blind spot" in threat analysis, potentially leading to a flawed and overly optimistic assessment of a facility's security [3]. This paper aims to address this gap.

The purpose of this report is to substantiate the necessity of the research and to develop a comprehensive quantitative model of the TILC formed by the induction of the electric field component of SEME from a loop source (MTE) onto a linear conductor (an accidental "electric dipole" antenna formed by ATES elements) located in Zone 1. The ultimate goal is to quantitatively assess the impact of this channel on the increase of the generalized Zone 2, which is critically important for the adequate design of TIS complexes [4].

II.THEORETICAL MODELING OF THE LEAKAGE CHANNEL

A. The SEME Source and its Near-Field

The SEME source in the MTE is modeled as an elementary loop with a time-varying current, which is a common representation for circuits on a printed circuit board [4]. According to Maxwell's equations, such a source creates a unified electromagnetic field [5]. It is crucial to distinguish between two regions:

The Near-Field (Zone 1): Also known as the induction zone, this is the area close to the source. Here, the electric and magnetic fields are not in phase, and their strength decreases rapidly with distance (as $1/r^2$ or $1/r^3$). This is the zone where the induction on nearby conductors (ATES) occurs.

The Far-Field (Zone 2): Also known as the radiation zone, this is the area far from the source where the fields are in phase and propagate as a plane wave, with their strength decreasing as $1/r$. This is the zone where remote interception by intelligence services is possible.

In this study, the key role is played by the tangential electric field component, E_ϕ. Its significant strength in Zone 1 is the primary driver for inducing a signal in nearby conductors [4].

B. The Accidental Antenna and Re-radiation Mechanism

Unlike closed loops that primarily react to the magnetic field, any ECE facility contains a large number of open conductors that act as accidental electric antennas (dipoles) [6]. Common examples include unshielded power and data cables, metal elements of furniture (e.g., desk legs, server rack frames), and building structures like window frames or reinforcing bars [4]. The electric field E_ϕ induces an electromotive force (EMF) along such a conductor. This EMF, in turn, drives a re-radiation current I_a. The magnitude of this current is critically dependent on the total impedance (Z_a) of the accidental antenna at the given frequency, which consists of its ohmic resistance, radiation resistance, and reactance [4, 6]. A low impedance, particularly near a resonant frequency, can lead to a very strong

re-radiation current, turning a passive piece of metal into an effective secondary transmitter.

C. Key Factors Influencing the Channel

The effectiveness of this leakage channel is determined by a combination of factors:

Source Characteristics: The strength of the initial SEME field, which depends on the current and the equivalent area of the source loop within the MTE.

Re-radiator Characteristics: The length, shape, and material of the accidental antenna, which define its impedance (Z_a) and its efficiency as a radiator [6].

Spatial Geometry: The distance between the MTE and the ATES, as well as their mutual orientation. Maximum energy transfer occurs when the conductor is aligned with the electric field vector [4].

Frequency: The frequency of the hazardous signal affects all aspects, including the source emission strength, the antenna's impedance, and its radiation efficiency.

III. ANALYSIS OF RESULTS AND IMPLICATIONS

The analysis of the proposed model shows that the presence of auxiliary technical equipment acting as accidental electric antennas leads to a significant and dangerous expansion of the overall information leakage zone. The signal re-radiated by the ATES coherently combines with the direct signal from the MTE. This summation creates a new, generalized Zone 2 boundary that significantly exceeds the original one calculated for the MTE alone [4].

It has been established that the degree of this expansion directly depends on the characteristics of the accidental antenna and its location. Even an ATES with weak re-radiative properties can increase the hazardous zone by tens of percent. In cases where the accidental antenna is effective (e.g., its length is close to resonant for the frequency of the hazardous signal), the radius of the hazardous zone can increase by one and a half times or more.

A critical implication is that the hazardous zone is no longer a simple sphere centered on the MTE. The presence of a re-radiator makes the zone asymmetric, extending further in the direction of the re-radiating object. This complicates security planning, as a single "safe distance" is no longer sufficient. It means that an area previously considered safe based on standard calculations may actually be under threat of information interception [3]. Thus, ignoring the leakage channel via the electric component leads to a gross underestimation of the real threats.

IV. CONCLUSIONS

This research substantiates the critical necessity of considering the information leakage channel formed by the induction of the electric component of SEME on accidental electric antennas [1, 4]. Ignoring this channel leads to a significant underestimation of the actual radius of the hazardous Zone 2, which jeopardizes the entire information security system at a facility.

The proposed model and quantitative analysis provide a tool for a more accurate and complete assessment of threats [2]. This is crucial for designing effective and reliable TIS systems and correctly defining the boundaries of controlled zones. The use of the "Principle of Potential Information Leakage Channels" (PILC) ensures a worst-case scenario assessment, which complies with the fundamental requirements of TIS practices [3, 4].

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