Volume XXIV 2021
ISSUE no.1
MBNA Publishing House Constanta 2021

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

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To cite this article: V. DOBREF, V. MOCANU, P POPOV and F. DELIU, Scientific Bulletin of Naval Academy, Vol. XXIV 2021, pg.75-82.

Submitted: 01.02.2021
Revised: 15.06.2021
Accepted: 22.07.2021

Available online at www.anmb.ro

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-21-I1-008

An energy approach of signal interference in marine environment

V Dobref[1], V Mocanu[2], P Popov[3], F Deliu[4]

[1]Professor PhD eng. , Naval Academy “Mircea cel Bătrân”, Constanța, RO
[2]University Assist. PhD Candidate, Naval Academy “Mircea cel Bătrân”, Constanța, RO
[3]Lecturer PhD, Naval Academy “MirceacelBătrân”, Constanța, RO
[4]Associate Professor PhD eng., Naval Academy “Mircea cel Bătrân”, Constanța, RO

E-mail: m.vladmocanu@gmail.com

Abstract. This study presents general theoretical aspects regarding electromagnetic field interferences. The main sources and their influence on GNSS systems of electromagnetic interference involved in the naval environment are exposed according to Septentrio GNSS Technology. Referring to new approaches of power supply in the marine industry, are highlighted studies that may attest the influence of wireless energy sources utilized in changing naval drones can influence GNSS systems.

Keywords:interference, marine environment, wireless power source

I. General aspects

In practice, electromagnetic interference - the process of interaction between two or more waves (oscillations) in an environment with constitutive parameters $(\varepsilon, \mu, \sigma)$ [128], usually known - mainly affects the electronic equipment, much more susceptible to disturbances; its study being the priority issue of Electromagnetic Compatibility (CEM/EMC).

Electromagnetic disturbances are of two types [1], [2], [3]:

- additive disturbances, when the usable and the disturbing signal add up:

$$s_p(t) = s(t) + p(t), \tag{1}$$

- multiplicative disturbances, when the usable and the disturbing signal multiply:

$$s_p(t) = s(t) \cdot p(t). \tag{2}$$

In electronic systems, it is considered, for simplification, that most of the disturbances that appear are additive, the multiplicative ones characterizing either the nonlinear environments (in which constitutive parameters are functions of the state quantities) or those in which one or more parameters vary randomly in time (parametric environments).

In linear environments, in which the principle of superposition applies, the overlap (in the sense of addition) of several waves of the same nature, described by the wave functions $\overline{\Psi}_i$, can be characterized by the equation [2]:

$$\overline{\Psi} = \sum_{i=1}^{n} \overline{\Psi}_i \,, \tag{3}$$

where: $\overline{\Psi}$ - represents the resulting wave-function.
This function-wave satisfies the equation (with partial, linear derivatives) of type d'Alembert:

$$\overline{\Psi} = \frac{\partial^2 \overline{\Psi}}{\partial x^2} + \frac{\partial^2 \overline{\Psi}}{\partial y^2} + \frac{\partial^2 \overline{\Psi}}{\partial z^2} + \frac{\partial^2 \overline{\Psi}}{\partial t^2} = 0. \qquad (4)$$

It can be stated that in linear environments the interfering waves do not interact with each other (in the sense that they do not influence each other in terms of energy), the effect of interference being felt only by the material point in the environment where this phenomenon occurs.

2. Energy aspects of signal interference

An analysis of the interference of the signals from the energetic aspect is presented below. From this point of view, it is useful to consider, first of all, the orthogonality of the signals. Thus, the energy of a signal can be defined as:

$$E_S = \|s(t)\|^2 = \int_{-\infty}^{\infty} s^2(t)dt\,, \qquad (5)$$

where:

$$\|s(t)\| = \sqrt{\int_{-\infty}^{\infty} s^2(t)dt} = N_s\,, \qquad (6)$$

represents the norm of the signal [4], [5], [6], [7].

It is assumed that the referred signals are measurable (respectively - of the integrable mode) and of finite energy (respectively - of the integrable square), the usual case in radio electronics. Under these conditions, it can be written:

$$\int_{t_1}^{t_2} |s(t)|dt \le k_1(<\infty); \quad \int_{t_1}^{t_2} s^2(t)dt \le k_2(<\infty); \; k_1, k_2 \in R. \qquad (7)$$

The scalar multiplication of two real signals is defined by the expression:

$$< s_1(t)s_2(t) >= \int_{-\infty}^{\infty} s_1(t)s_2(t)dt\,. \qquad (8)$$

As a physical sense, the integral of the right-hand side of the relationship (8) represents the mutual energy of the two signals; in other words - energy is transferred from one to another in a process of energetic interference.

If the scalar multiplication of two signals is zero, then the signals are orthogonal:

$$< s_1(t)s_2(t) >= \int_{-\infty}^{\infty} s_1(t)s_2(t)dt = 0\,. \qquad (9)$$

Such orthogonal signals are the components of a physical signal (measurable, of finite energy), obtained on an independent linear basis (of coordinates), orthogonal $\{f_i(t)\}$, in the form of a series of functions, under the conditions:

• for any $s(t)$, there is a $\alpha_i \in R$, so that:

$$s(t) = \sum_{i=1}^{n} \alpha_i f_i(t); \qquad (10)$$

$$\sum_{i=1}^{n} \alpha_i f_i(t) = 0 \text{ presupune } \quad \alpha_i = 0. \tag{11}$$

As a result, any physical signal can be obtained starting from a linear base, as a sum of signals $f_i(t)$ that compose the base, by weighting with real coefficients [6].

The conditions for a linear base to be orthogonal are:

$$< f_i(t) f_j(t) >= \begin{cases} k_i\,,\ pentru\ i = j \\ 0,\ \ pentru\ i \neq j \end{cases} \tag{12}$$

where:

$$k_i = N_{si}^2 = \| f_i(t) \|^2 = < f_i(t) f_i(t) >= \int_{-\infty}^{\infty} f_i^{\,2}(t) dt = E_{si} \tag{13}$$

represents the square of the signal norm $f_i(t)$, respectively its energy, E_{si}.

If $N_{si}^2 = 1$, then the linear base is called orthonormal.

Regarding the presented ones, we can give as an example the (usual) representation of the non-sinusoidal periodic signals with the help of the generalized Fourier series, in which case the component functions of the system are generally considered to be complex.

If the signal $s(t)$ can be represented in the form of a generalized Fourier series, on an orthogonal basis, then, according to Parseval's relation:

$$E_S = \int_{t_1}^{t_2} \sum_{i=1}^{n} (\alpha_i \cdot f_i(t))^2 dt = \sum_{i=1}^{n} \alpha_i^{\,2} \tag{14}$$

It follows that the signal energy is given by the sum of the energies of the components $f_i(t)$ of the respective Fourier series, with the specification that the circuit is considered linear.

Regarding the representation of a signal $s(t)$ by a generalized Fourier series, the following specifications are required:

a) the finite time interval $[t_1, t_2]$, on which the signal is defined, must coincide with the time interval over which the functions $f_i(t)$ are orthogonal;

b) the choice of the orthogonal series of functions $\{f_i(t)\}$ is made in such a way that the functions $f_i(t)$ are as simple as possible, easy to generate by electronic means, and able to ensure a fast convergence of the Fourier series for as few terms as possible.

In technique, trigonometric functions, polynomials Legendre, Laguerre, Hermite, Chebyshev, Iacobi, Walsh, etc. are used as functions that constitute orthogonal systems. (tab. 1) [8].

Table 1. Characteristics of orthogonal polynomials

The polynomial	**Weight function**	**The orthogonal interval**	**The form of the first terms**

The polynomial	Weight function	The orthogonal interval	The form of the first terms
LEGENDRE	1	-1,1	$P_0(x)=1; P_1(x)=x,$ $P_2(x)=0{,}5(3x^2-1)$ $P_3(x)=0{,}5(5x^3-3x)$
LAGUERRE	e^{-x}	$0,\infty$	$L_0(x)=1; L_1(x)=1-x$ $L_2(x)=1-2x+0{,}5x^2$ $L_3=1-3x+\frac{2}{3!}x^2-\frac{1}{3!}x^3$
HERMITE	$e^{-\frac{x^2}{2}}$	$-\infty,+\infty$	$H_0(x)=1; H_1(x)=x$ $H_2(x)=x^2-1$ $H_3=x^2-3x$
CEBÂŞEV	$\frac{1}{\sqrt{1-x^2}}$	-1,1	$T_0(x)=1; T_1(x)=x$ $T_2(x)=2x^2-1$ $T_3=4x^3-3x$
IACOBI	$(1-x)^{\alpha}(1+x)^{\beta}$ **cu:** $\alpha>-1$ $\beta>-1$	-1,1	$P_n^{(\alpha,\beta)}(x)=\frac{(-1)^n}{2^n\cdot n!}(1-x)^{\alpha}$ $(1+x)^{-\beta}\frac{\partial^n}{\partial x^n}[(1-x)^{\alpha+n}$ $(1+x)^{\beta+n}]$

Returning to the problem of signal interference, it can be seen that in the analyzed case - of the decomposition of a signal into series of orthogonal functions - we can speak of interference in the sense of addition (overlap) of the component signals, which is the usable signal; on the other hand, it can not be an energetic interference of the component signals, their mutual energy being zero (in a linear environment).

Obviously, if there had been such an energy interference, the resulting signal, $s(t)$, would have been affected, both in form and energy.

On the other hand, whenever two signals interfere multiplicatively, respectively in the structure of the resulting signal appear terms containing their non-zero product, we can speak of a product interference of the signals and, consequently, of an energetic interference of them. Such situations are encountered by overlapping the signals on nonlinear electronic devices, the expression of the disturbed resulting signal containing the product of the amplitudes of the usable signal and the disturbing one.

As examples of the energetic approach of signal or wave overlap (in the case of multiplicative interference) the following may be present:

1. The case in which the disturbing signal is transferred directly on the usable signal, the process being similar to a multiplication amplitude modulation [4], [5]. In this sense, the interference of two harmonic oscillations, one useful and one disturbing, having different frequencies, in a modulation process will be analyzed. Either the signals $u_u(t)$and $u_p(t)$, harmonics:

$$u_u(t) = U_u \cos(\omega_u t), \tag{15}$$

$$u_p(t) = U_p \cos(\omega_p t), \tag{16}$$

where: $u_u(t)$- usable voltage (unmodulated), also called the carrier,

$u_p(t)$- a permanent disturbing voltage, with $U_p << U_u$.

In the conditions in which the disturbance is transferred directly on the usable signal, the amplitude of the resulting signal becomes:

$$U(t) = U_u \cdot k \cdot u_p(t), \tag{17}$$

where: U_u is the amplitude of the carrier, $u_p(t)$is the modulating signal (disturbing); the factor *k* can even have the value 1.

The resulting signal becomes:

$$u(t) = U(t) \cdot \cos(\omega_u t) = U_u \cdot k \cdot u_p(t) \cdot \cos(\omega_u t); \tag{18}$$

or, taking into account relation (2.12), it will take the form:

$$u(t) = U_u U_p k \cos(\omega_u t) \cos(\omega_p t). \tag{19}$$

Relation (19) highlights a product amplitude modulation (AM).

2. The systemic conception on energy bases, referring to the deforming regime, of acad. I. S. Antoniu, according to which:

- there are interactions between the energy levels of the harmonics of a non-sinusoidal periodic wave just as there are interactions between part and whole, between the system and its components, with the specification that such interactions occur only in nonlinear circuits;
- the function that characterizes the interaction between the energy levels of the harmonic components is represented by the deforming power [9].

4.Interference in marine traffic

According to the study published by Septentrio GNSS Technology: ”GNSS signals are expected to travel more than 20,000 km and still arrive fit for high-precision position calculations. In most cases, the satellite signals arrive relatively unscathed albeit with very low power. With GNSS signals barely distinguishable from the thermal noise, as figure 1 shows, it is relatively easy for them to be disrupted by a nearby interferer transmitting at the milliwatt level”

GNSS - Global Navigation Satellite System consists of a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. GNSS Frequencies and Signals are around 1k MHz. All GMDSS users can use this data to determine location. – according to EUSPA - European Space Sgency.

”Precise Point Positioning (PPP) is a technique that employs corrections to the satellites broadcast orbit and satellite clock. In addition to the satellite errors the GNSS signal is delayed or advances as it travels through the atmosphere and the signal must be corrected. Typically, a PPP correction service broadcasts information that enables the computation of an ionospheric correction. A tropospheric correction is estimated using a reference model.” - according to Tallysman Company.

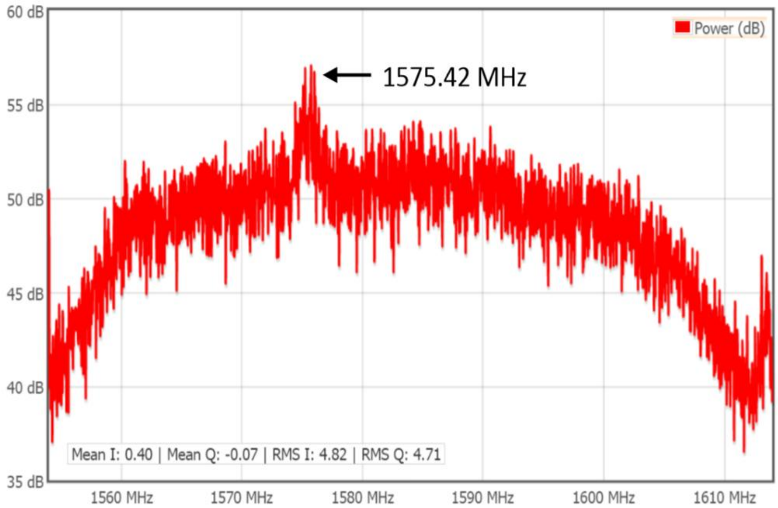

Figure 1. Spectrum plot of the L1 band without interference with the GPS L1C/A central frequency indicated (Septentrio Company)

The most common sources of interference in the marine environment are: radio amateurs, navigation beacons, self-interference, Inmarsat/Iridium uplinks, intentional jammers.

Another recent source of interference in the marine environment is wireless charging systems, which have begun to be used both for ship shore connection and for charging various aerial /naval drones.

As can be seen in the experiment published by [10], even for low power wireless charging sources, the electric field intensity has a considerable value, figure 2.

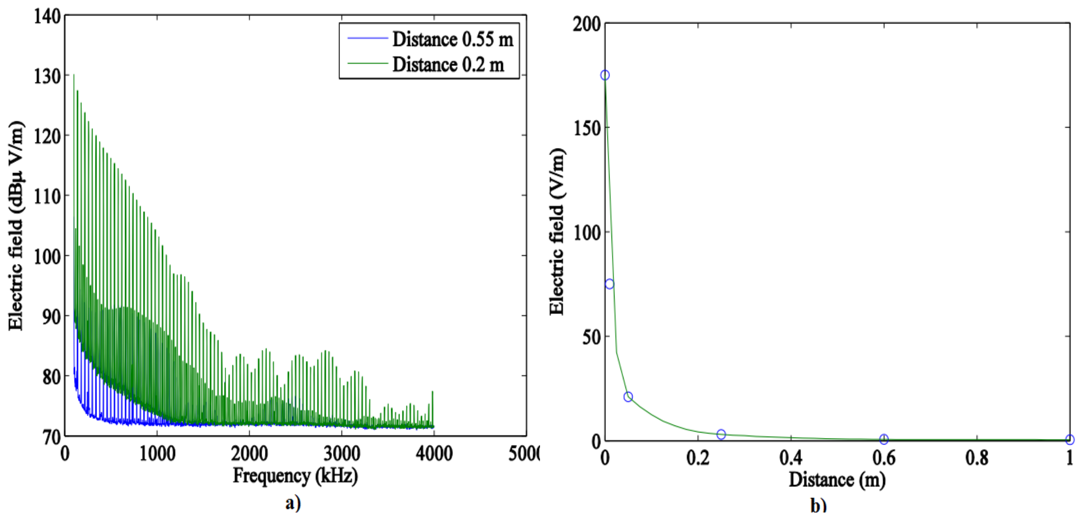

Figure 2. a) Electric field intensity in WPT system for different distances,
b) Electric Field amplitude at the distance from the WPT system [10]

At high power values of wireless charging systems, as presented in the article [11], the interference values increase figure 3, thus disrupting maritime traffic.

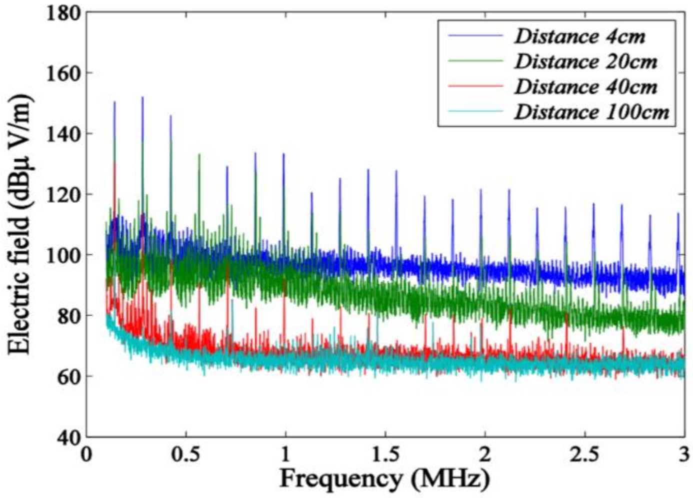

Figure 3.Electromagnetic interferences generated by WPT system at different distance of measurement [11]

As a countermeasure to the interference produced by electromagnetic waves produced by wireless charging systems, it must take into account the following aspects:

- wavelength adjustment by sizing the wireless energy emission coils,
- choosing the electromagnetic wave propagation frequencies that offer high efficiency of wireless energy transfer but with not interfere with GNSS frequencies,
- choosing amplitudes of electromagnetic waves for wireless energy transfer as low as possible but maintaining a high wireless transfer efficiency,
- shielding of wireless energy transfer systems.

5. Conclusions

The electromagnetic emissions measurement produced by different sources plays an important role in electromagnetic compatibility study between navigation systems and disruptive sources from the naval environment.

The energy interference of the signals is a phenomenon that must be taken into account in the case of non-linear circuit elements of electrical equipment because it can change the power of usable signals, in the sense of amplification or decrease, with direct consequences on the normal operation of this equipment. A similar phenomenon can occur in power supply networks, which can lead to unwanted increase in the power of some harmonics, with undesirable implications on electrical equipment, such as voltage or current resonance phenomena.

The practical solutions consist in measures to attenuate the interference phenomena, in the case of electronic equipment (filters, screens etc.), or to limit the harmonics, in the case of electrical equipment (filter-compensation devices).

6. References

[1] A. Sotir,Interferențeelectroenergeticeperturbatoare. Bazeteoretice, Ed. Militară, București, 2005.

[2] A. MIHALCEA, „Prelucrareaoptimă a semnalelorînsistemeinformaționale", Ed. Militară, București, 1987.

[3] G.S. GORELIC, Teoriacâmpului electromagnetic, Ed. DidacticășiPedagogică, București, 1981

[4] INCEU V. Analizasemnalelorşicircuitelor, Note de curs, EdituraAcademieiNavaleMirceacelBătrân, Constanţa, 1992.

[5] CARTIANU G., Analizaşisintezacircuitelorelectrice, EdituraDidacticăşiPedagogică, Bucureşti, 1972.

[6] POPESCU V., Semnale, CircuiteşiSisteme, partea I: TeoriaSemnalelor, Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, 2001.

[7] SĂVESCU M., PETRESCU T., CIOCHINĂ S., Semnale, CircuiteşiSisteme. Probleme, EdituraDidacticăşiPedagogică, Bucureşti, 1981.

[8] MARGHESCU I., BĂDESCU G., Transmitereadiscretă a semnalelor, EdituraTehnică, Seria Electronica Aplicată, Bucureşti, 1978.

[9] I.S.ANTONIU, Chestiunispeciale de electrotehnică, Ed. AcademieiRomâne, București, 1956.

[10] Elena N. Baikova, Stanimir S. Valtchev, R. Melício, Vítor M. Pires, Electromagnetic Interference from a Wireless Power Transfer System: Experimental Results, International Conference on Renewable Energies and Power Quality, Madrid (Spain), May 2016, ISSN 2172-038 X, No.14 May 2016.

[11] E. N. Baikova, S. S. Valtchev, R. Melicio, A. Krusteva, V. FernãoPires, Study of the Electromagnetic Interference Generated by Wireless Power Transfer Systems, International Review of Electrical Engineering (I.R.E.E.), Vol. 11, N. 5, ISSN 1827- 6660, September – October 2016.