A FUZZY-MEASUREMENT ALGORITHM FOR ASSESSING THE IMPACT OF ELECTROMAGNETIC FIELDS ON HEALTH

by

Saša D. MILIĆ*[*], *Branislav D. VULEVIĆ, and Djordje M. STOJIĆ*

Electrical Engineering Institute "Nikola Tesla", University of Belgrade, Belgrade, Serbia

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In this paper we propose a novel fuzzy-measurement algorithm for the assessment of the impact of electromagnetic fields on human health. The algorithm was developed to unify complex and diverse measuring methodologies, standards and fuzzy logic control into a single entity – a comprehensive methodology for the assessment of the impact of electromagnetic fields on humans. The algorithm will enable multiple criteria automated assessment based on measurement results and the existing electromagnetic field standards, guidelines and recommendations in order to avoid potential subjectivity and varied approach. We have therefore considered two classes of fuzzy logic systems (Type-1 and Type-2) and developed a graphic model intended for scenarios where expert opinions differ and where such a difference might significantly affect the assessment. The fuzzy model was developed on the principles of the proposed algorithm and this resulted in a unique procedure for the assessment of all types of electromagnetic fields on human health.

Key words: measurement of electromagnetic field, human health, fuzzy measurement algorithm, fuzzy logic system

INTRODUCTION

Man-made electric, magnetic and electromagnetic fields (EMF) have become omnipresent in the environment. For the high frequency (100 kHz to 300 GHz) and radiofrequency (RF) ranges, the main sources of EMF have, up to now, been radio and TV transmitters and cellular mobile communication systems. This raised concerns as to the potential adverse effects of such exposure on human health. A variety of epidemiological studies have suggested that EMF, virtually over all the frequency spectrum (0 Hz-300 GHz), might be a risk factor for several health endpoints, including cancer and neurodegenerative disease [1].

This paper presents a novel fuzzy-measurement algorithm (FMA) which is based on the theories of fuzzy logic and measurement of EMF. The algorithm takes into account the key fact: each measuring system is the collection of instruments or gauges, standards, operations, methods, fixtures, software, personnel, environment, and assumption used to quantify a unit of measure or fix assessment [2].

Magnetic fields can be characterized according to a number of parameters, i. e., magnitude, frequency, polarization, etc. Measuring of one or more of these parameters and circumscribing how they might relate to human exposure, may serve as possible goals of a measurement algorithm [3].

Theory of fuzzy logic, as one of the most suitable theories for decision making, has attracted a growing interest of researchers across a range of measuring areas. This theory shows knowledge, experience, and subjective viewpoints of decision maker in natural language format [4].

In general, this paper presents a practical implementation of Zadeh's basic concept of fuzzy logic: *Fuzzy logic provides a foundation for the development of new tools for dealing with natural languages and knowledge representation*.

The main goal was to develop an algorithm based on the aforementioned theories that would be adequately robust and comprehensive to be used to measure EMF and assess their impact on human health.

Intermittent operating modes of transmitters of different EMF sources (*e. g.* base stations) significantly affect the measuring process and the data obtained thereof, and consequently affects the assessment.

The association of a fuzzy set to a linguistic term offers the principal advantage in which measurement

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[*] Corresponding author; e-mail: s_milic@yahoo.com

experts articulate their knowledge through the unified use of linguistic terms and measurement methods. The fuzzification considers uncertainty which may be affected in the outputs and consequently in the final decision [5].

Validation of the proposed algorithm uses a fuzzy model based on fuzzy logic systems Type-1 (FLS-T1) and fuzzy logic systems Type-2 (FLS-T2) and is developed by MATLAB for Universal Mobile Telecommunications System (UMTS) that usually works in the frequency band around 2 GHz. Fuzzy rules and membership functions were derived from the knowledge and experience gained in situ and in the laboratory environment. All input parameters and intervals of the fuzzy model were adopted from the levels referenced in the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [6].

The RF-EMF exposure and health effects

One of the main issues of today is: *What major health hazards do we face*? A large number of researchers, in several scientific fields, are trying to give the answers. Risk assessment and risk management constitute a unique approach that plays a leading role in defining strategies to reduce the impacts of adverse and unwanted effects on human health and implementation of protection measures. Basically, this paper presents the practical implementation of the aforementioned theories. Risk assessment is the process of using various methods to estimate how much harm an exposure to EMF can cause to human health. Risk management involves deciding whether or how to reduce this exposure to a certain degree.

Exposure to radio frequency electromagnetic fields (RF-EMF) is an unavoidable fact of modern life. Significant public and media concerns have been raised regarding the increase in RF-EMF exposure of the general population and its potentially adverse effects on health, particularly in children.

The question of whether the children are more vulnerable to RF-EMF exposure than adults has been widely debated in the scientific community [7]. An overview of the scientific literature on RF-EMF characterization of exposure within the European population is at [8].

The International Agency for Research on Cancer (IARC) has released a detailed evaluation of cancer risks associated with RF-EMF, which designates RF-EMF as *a possible human carcinogen* [1, 9, 10].

The precautionary approach provides justification for public policy actions in situations of scientific complexity, uncertainty and ignorance, where there may be a need to act in order to avoid or reduce potentially serious or irreversible threats to health or the environment, using an appropriate level of scientific evidence and taking into account the likely pros and cons of action and inaction [8].

Fuzzy logic and fuzzy reasoning

Logic could be interpreted as a study of methods and principles of reasoning, where reasoning means obtaining new propositions from existing propositions. Fuzzy logic can be conceptualized as a generalization of classical logic. In fuzzy logic, which is also sometimes called diffuse logic, there are not just two alternatives but a whole continuum of truth values for logical propositions. Often in practice, for the same set of fuzzy rules, different fuzzy logic systems can be used [11, 12].

Various measuring techniques and measurement systems are affected by measurement uncertainties. Many of them could be processed via fuzzy logic system Type-1 (FLS-T1) which have crisp and precise membership values. However, crisp membership values of FLS-T1 can in some cases be a disadvantage, *e. g*. when opinions of measurement experts differ. In such cases, it is recommended to use fuzzy logic systems Type-2 (FLS-T2). A FLS T2 is characterized by a fuzzy membership function, that is, the membership value for each element is in itself a fuzzy set in [0,1]. The membership functions of FLS-T2 are three dimensional and include a footprint of uncertainty.

MEASUREMENT METHODOLOGY

Electric and magnetic fields can be characterized according to a number of parameters such as magnitude, frequency, polarization, *etc*. The measurement methodology of EMF is determined and defined by standards [9, 10, 13, 14]. In this paper, we propose a novel FMA intended to unify and automatize measurement procedures for EMF ranges of 10 MHz to 300 GHz.

The fig. 1 illustrates the entire process that led to the development of the metrological aspect of the complex fuzzy logic algorithm intended for the assessment of the extent to which EMF affect human health, as well as for defining potential measures for protection. The novelty aspect of the presented procedure lies in the definition of procedural steps, their sequence and interconnection.

The foundation is in the standards, recommendations and regulations that are governed by national and international legal frameworks [9, 10, 13, 14]. The sequence of processes is important, and it begins with identifying the source or sources of emission. This step is important for two reasons: in order to determine the frequency range that will be measured, as well as the level of influence of the respective sources, if multiple sources are involved. The next step defines the type of field that will be measured at the chosen location - electric, magnetic, or both, depending on the requirements and the technical capabilities of the measuring equipment. It is important to define the frequency of the measured field, because fields of the

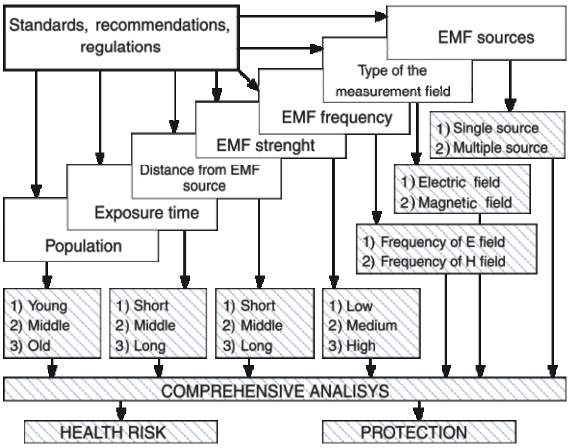

Figure 1. Pathway for the design of the EMF measuring procedure, comprehensive analysis, assessment, and proposal of protection measures

same strength but with different frequencies will impact human health differently and will require different measures for protection. The distance between the measuring location and the identified and defined source, or sources of emission is important, because recommendations regarding reducing the adverse effects are often based on increasing the distance from the source. Unfortunately, this is often impracticable, particularly where residential and business premises or other fixed locations are concerned and where increasing the distance from the EMF source is not an option. The exposure time is another factor of key importance for the assessment of endangerment and is an important element in establishing of the fuzzy rules that the algorithm is based on. The final step in the hierarchical sequence of activities is the defining of the population exposed to the emission. This step was introduced after concerns that the younger population is more susceptible to health risks, was identified. Without testing this view, the step was also incorporated into the new fuzzy algorithm for the assessment in order to demonstrate its ability to encompass all the potential requests pertaining to current and future users and/or new legal requirements.

CLASS SELECTION OF FUZZY LOGIC SYSTEM

Modern fuzzy logic was developed in the mid-1960s by Lotfi Zadeh, to enable modeling problems where imprecise data had to be used, or in which the rules of inference were formulated using a very generalistic approach that incorporated diffuse categories.

Scenario 1 – use of FLS Type 1 (FLS-T1)

Unlike probability, fuzzy logic places imperfection in the informational content of the event. The extension principle is a basic concept of the fuzzy set theory that provides a general procedure for extending crisp domains of mathematical expressions to fuzzy domains. In the fuzzy set A, each element is mapped to [0, 1] by membership function μ_A:X [0, 1], where [0, 1] means real numbers between 0 and 1 (including 0 and 1).

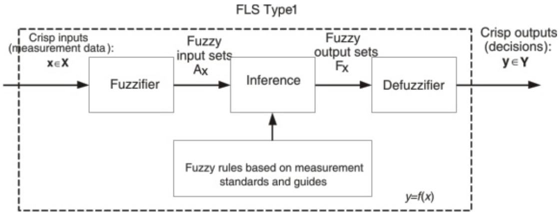

Figure 2. The FLS Type-1

In an attempt to mimic human actions in the EMF measuring procedure (refer fig. 1), FLS-T1 is composed of four main components (refer fig. 2): fuzzifier, fuzzy rules, inference engine, and defuzzifier [15].

Scenario 2 – use of FLS Type 2 (FLS-T2)

There are at least two reasons for considering the applications of FLS-T2. The first is the uncertainty of measurement results, and the second the differing expert opinions in creating fuzzy rules.

A FLS described using at least one Type 2 fuzzy set is called a Type-2 FLS [16-18]. Type-1 FLS are unable to directly handle rule uncertainties, because they use Type-1 fuzzy sets that are certain (viz, fully described by single numeric values). On the other hand, Type-2 FLS, are useful in circumstances where it is difficult to determine an exact numeric membership function, and there are measurement uncertainties [19].

If the value of a membership function is given by a fuzzy set, it is a Type-2 fuzzy set. A Type-2 fuzzy set is characterized by the membership function

$$\tilde{A} \quad \{((x,u),\mu_{\tilde{A}}(x,u)) \,|\; x \quad X, \; u \quad J_x \quad [0,1]\} \quad (1)$$

in which $0 \quad \mu_{\tilde{A}}(x,u) \quad 1$. In fact, $J_x \quad [0,1]$ represents the primary membership of x, and $\mu_{\tilde{A}}(x,u)$ is a Type-1 fuzzy set known as the secondary set.

In an attempt to mimic human actions of measurement procedure of EMF, a FLS – Type – 2 is composed of five main components: fuzzifier, fuzzy rules, inference engine, type reducer and defuzzifier. The type-reducer generates a Type-1 fuzzy set output, which is then converted in a numeric output through running the defuzzifier. The FLS-T2 can be regarded as a collection of a large number of Type-1 FLS's. The type-reducer generates a Type-1 fuzzy set output, which is then converted in a numeric output through running the defuzzifier. The type reduced set Y is a collection of the outputs of all embedded Type-1 FLS's (refer fig. 3). A crisp output can be obtained by aggregating the outputs of all the embedded Type-1 FLS's [20, 21].

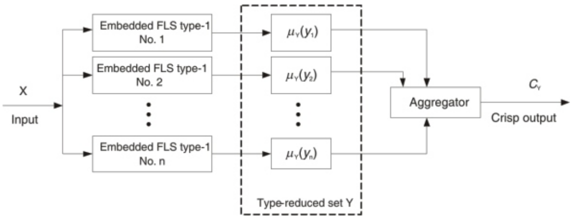

Figure 3. The FLS Type-2 can be imagined as a large number of FLS Type-1 [19]

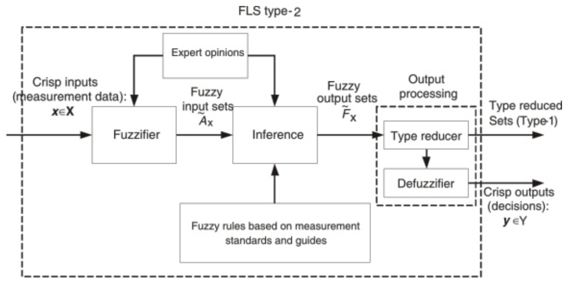

Figure 4. The FLS Type-2

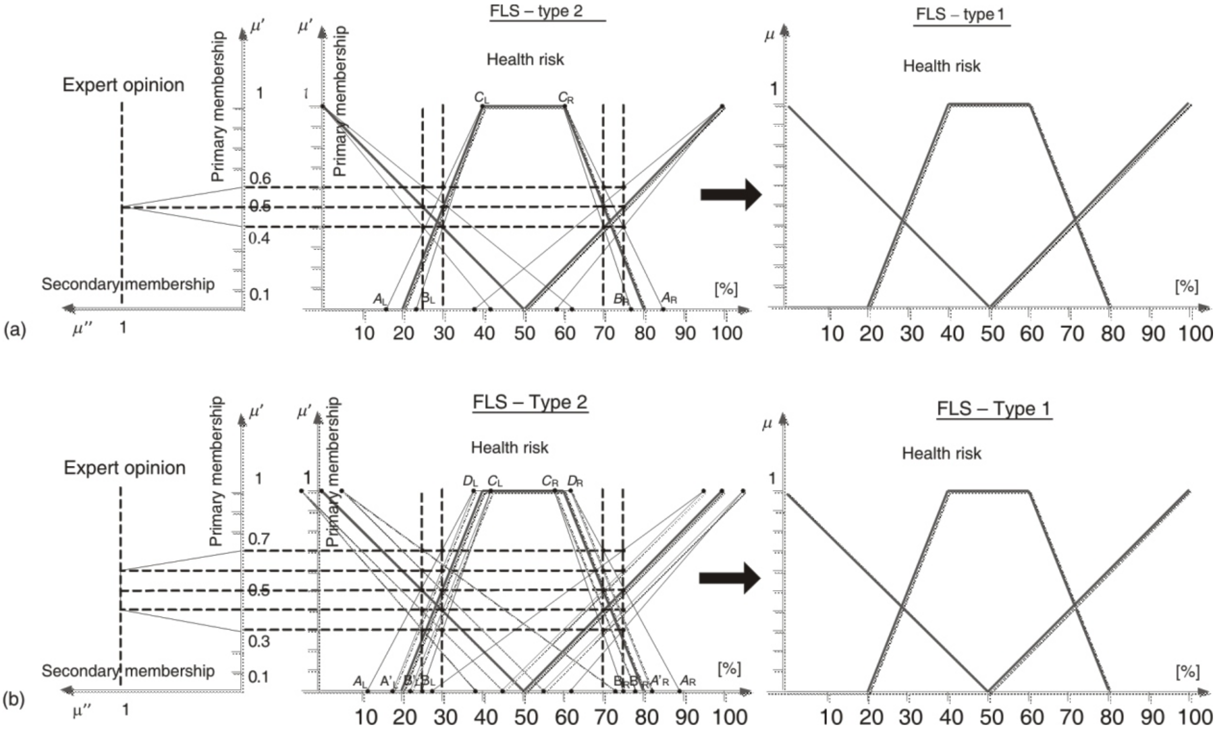

Figure 5. Type-2 fuzzy sets: (a) construction of FOU – primary membership is triangular fuzzy number, (b) construction of FOU – secondary membership is trapezoidal fuzzy number

Figure 4 shows the sixth component – expert opinions. Unlike the standard FLS Type-2model as referred to at [16-21], this component derives from conforming of an FLS Type-2 model to metrological requirements pertaining to scenarios where multiple and differing expert opinions exist regarding both the assessment of input measurements and the decision making process. This impact can affect two phases of the fuzzy algorithm:

- The fuzzification phase, where the membership function of the input measurement data is also a fuzzy number (scenario where the experts disagree on measured values and measurement conditions, such as impact of the unknown EMF sources, number of the unknown EMF sources, spatial allocation of measurement points, weather conditions, impact of proximal objects, *etc.*)
- The inference phase where the membership function of fuzzy numbers that represent decision making is also a fuzzy number.

It frequently occurs in metrology that the final assessments and recommendations on health risks based on EMF measurements in real life conditions vary. This comes as a consequence of conflicting expert opinions on the level of impact that unknown sources of emission, proximal objects or forests have. Based on experience and a large number of processed EMF measurements, the authors have concluded that expert opinions (where multiple opinions exist) can be represented by fuzzy number in two shapes, a triangle fig. 5(a) and a trapezoid fig. 5(b). Triangular is used in a scenario where the left and right deviation from the middle value needs to be represented. This would correspond to the first scenario from fig. 5(a) which represents a situation where 50 % of experts share a common opinion on the health impact (primary membership, PM = 0.5), while 10 % believe that the impact is lesser (PM = 0.4), or greater (PM = 0.6). This is a common scenario in practice. The footprint of uncertainty (FOU) is also triangular $A_LB_LC_L$ (left from the middle value), or $A_RB_RC_R$ (right from the middle value).

A second scenario is possible, where a greater number of experts are involved and where the entire population of expert opinions must be represented. In such scenarios, it is more convenient to use a trapezoid refer fig. 5(b) as a fuzzy number for PM where the upper base of the trapezoid represents the range ratio of experts in agreement (range ratio of agreement), while its left and right sides represent differing opinions (deviations). The FOU in this case has the shape of a trapezoid $A_L B_L C_L D_L$ (left from the middle value), or $A_R B_R C_R D_R$ (right from the middle value). Within the trapezoids $A_L B_L C_L D_L$ and $A_R B_R C_R D_R$, are the parallelograms $A'_L B'_L C_L D_L$ and $A'_R B'_R C_R D_R$, that result from the upper smaller base of the trapezoid, representing the probability of agreeing expert opinions of 40 %-60 % in fig. 5(b) abscissa values 0.4-0.6.

DECISION MAKING ON THE BASIS OF COMPREHENSIVE FMA

Large amounts of available measuring methods, procedures and standards as well as theories for managing, controlling and assessment, cause a significant need for summarization and establishing of a legal framework for their easier practical implementation. Our findings indicate the necessity of EMF measuring and fuzzy logic synergy. Higher quality results from measured data provide stronger support for the assessment and decision making in this context.

In the literature it is possible to find different algorithms related to the decision-making processes using the fuzzy logic [22, 23]. So far, no comprehensive algorithms have been developed that incorporate measurement procedures and standards relating to the impact of radiation on humans.

Fuzzy and measurement model assumptions

The following assumptions were used to develop the fuzzy model for automated drawing of conclusions pertaining to electromagnetic measurements:

- ICNIRP guidelines (International Commission on Non-Ionizing Radiation Protection) [6] is applied for limiting exposure to electromagnetic fields.
- The measured data belong to the considered frequency range.
- The affected people under study are people of all ages.
- The output values of the presented algorithm are the levels of health impacts and protection needs.

Fuzzy-measurement algorithm

The FMA consists of two main parts, measurement and fuzzy, as shown in the block diagram refer fig. 6. Recent advances have offered some new approaches and solutions to the decision making problems. Full advantage of the proposed algorithm is achieved when it is applied for to all electrical and

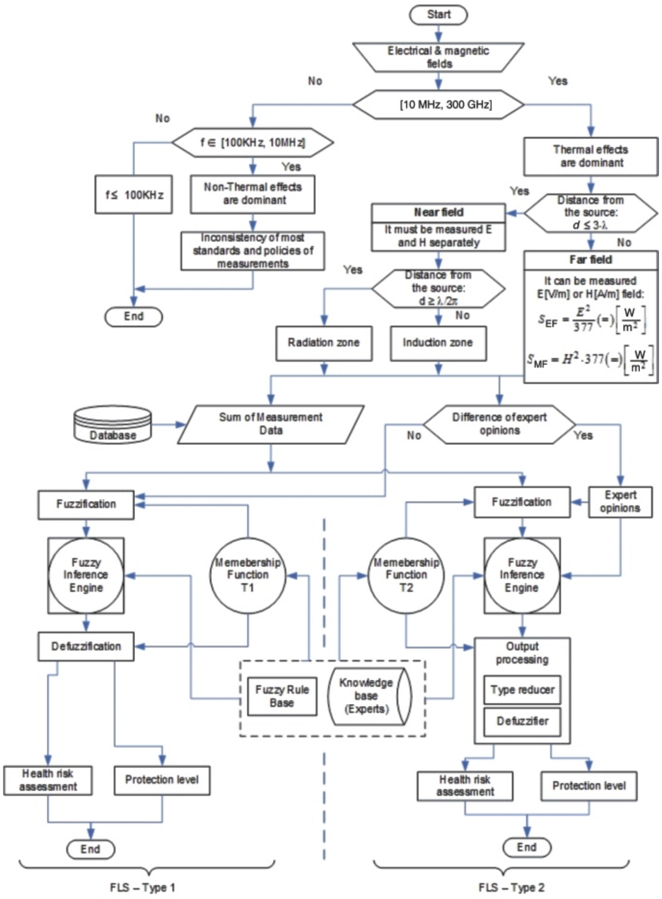

Figure 6. The FMA

magnetic field strengths and frequencies. The second part of FMA (fig. 6), which pertains to the assessment, was developed using the FLS-T1 or FLS-T2, depending on whether there is a discrepancy between the expert opinions.

THE FMA TESTING AND VALIDATION

The fuzzy modeling has gained enormous interest in the last decade, because it is a powerful solution to approximate non-linear models by aggregating linear local models with non-linear weighting functions. [24-26].

Validation of the proposed algorithm is performed using a fuzzy model (developed in MATLAB) for Universal Mobile Telecommunications System (UMTS) – 2GHz. If we use only the measuring results of EMF and international standards, it is sufficient to apply FLS-T1 in the FMA. However, it is often necessary to take into account the differences of expert opinions about health risk and exposure time. In that case, for the purpose of a comprehensive analysis, it is not just enough to take into account the value of EMF limits [6] and fuzzy sets Type-1, but it is necessary to use Type-2 fuzzy sets and their corresponding membership functions.

Testing and validation based on FLS-Type1

We consider two forms of fuzzy of numbers (traingletriangle and trapeze) with different degrees of membership functions (2) and (3).

$$\mu(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{c-a}, & a \le x \le c \\ \dfrac{e-x}{e-c}, & c \le x \le e \\ 0, & x \ge e \end{cases} \tag{2}$$

Table 1. Membership Functions of FLS-T1

Membership functions (inputs and outputs)	Group/Class	Fuzzy intervals:
		Triangle {a; c; e}
		Trapezoid {a; b; d; e}
Electrical field (input) $[\mathrm{Vm}^{-1}]$	Low	[0; 0; 16]
	Medium	[0; 28; 61]
	High	[28; 61; 70; 70]
Exposure time (input) [min]	Short	[0; 0; 6; 10]
	Middle	[0; 10; 20; 30]
	Long	[20; 30; 40; 40]
Age (input) [in year]	Young	[0; 0; 20; 40]
	Middle	[35; 50; 60]
	Old	[55; 80; 100; 100]
Health risk (output) [%]	Low	[0; 0; 50]
	Medium	[20; 40; 60; 80]
	High	[50; 100; 100]
Protection (output) [relative values]	No	[0; 0; 0.2; 0.5]
	Further analysis	[0.3; 0.4; 0.6; 0.7]
	Yes	[0.5; 0.8; 1; 1]

$$\mu(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le d \\ \dfrac{e-x}{e-d}, & d \le x \le e \\ 0, & x \ge e \end{cases} \tag{3}$$

Making decisions is achieved by using FMA (see fig. 6) and complex if-then rules. Input parameters (tab. 1) are: E field [V/m], Exposure time [min] and age [year]. Output parameters (tab.1) are: health risk [%] and protection need [relative unit].

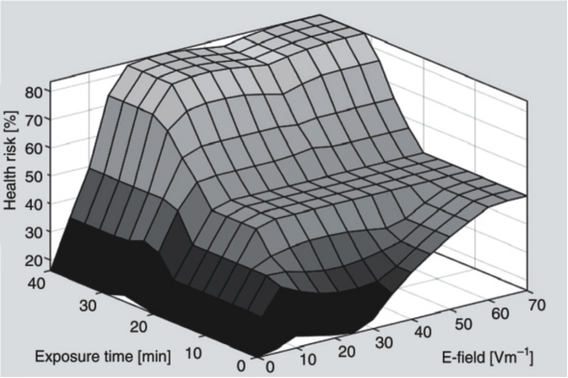

Figure 7. Health risk is a function of exposure time and E field

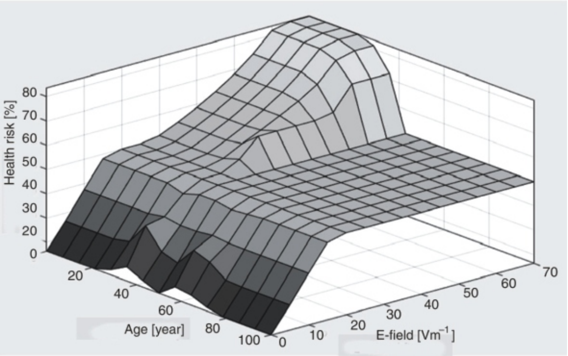

Figure 8. Health risk is a function of Age and E field

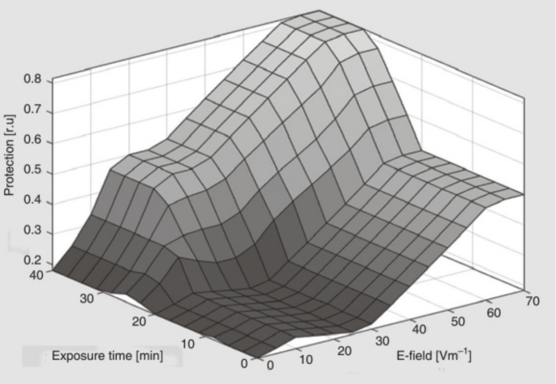

Figure 9. Need for protection is a function of exposure time and E field

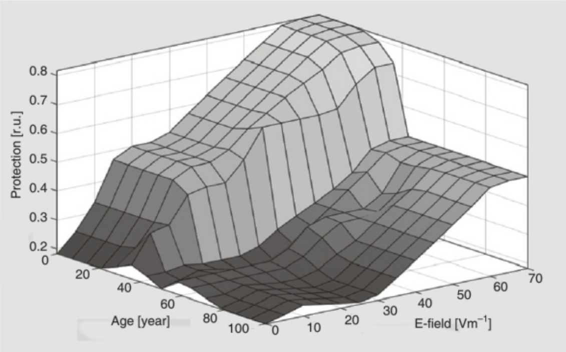

Figure 10. Need for protection is a function of Age and E field

Table 2. Membership functions of FLS-T2 (fuzzy set I)

Membership functions (inputs and outputs)	Group/Class	Fuzzy intervals:
		triangle $\{a; c; e; \mu\}$
		trapezoid $\{a; b; d; e; \mu\}$
Exposure time (input) [min] blurred MF	Short	[0; 0; 20; 1] [0; 0; 15; 0.8]
	Middle	[5; 25; 35; 55; 1] [10; 28; 32; 50; 0.8]
	Long	[40; 60; 60; 1] [45; 60; 60; 0.8]
Health risk (input) [%] blurred MF	Low	[0; 0; 6; 73; 1] [0; 0; 38; 1]
	Medium	[12; 38; 63; 89; 1] [25; 42; 58; 75; 1]
	High	[28; 95; 105; 105; 1] [62; 100; 100; 1]
Protection (output) [crisp value]	No	[0]
	Further analysis	[0.5]
	Yes	[1]

Table 3. Membership functions of FLS-T2 (fuzzy set II)

Membership functions (inputs and outputs)	Group/Class	Fuzzy intervals:
		Triangle $\{a; c; e; \mu\}$
		Trapezoid $\{a; b; d; e; \mu\}$
Exposure time (input) [min] blurred MF	Short	[0; 0; 25; 1] [0; 0; 15; 1]
	Middle	[0; 25; 35; 60; 1] [10; 30; 30; 50; 0.8]
	Long	[35; 60; 60; 1] [45; 60; 60; 1]
Health risk (input) [%] blurred MF	Low	[0; 0; 6; 70; 1] [0; 0; 50; 1]
	Medium	[12; 38; 63; 89; 1] [25; 50; 52; 75; 1]
	High	[30; 94; 100; 100; 1] [50; 100; 100; 1]
Protection (output) [crisp value]	No	[0]
	Further analysis	[0.5]
	Yes	[1]

The relationships of input and output parameters are illustrated in figs. 7-10, which were obtained as results of the FLS-T1 modeling (fuzzy rules based on FMA).

Testing and validation based on FLS-Type2

As we have previously emphasized, in practice, there are at least two reasons to consider the prior consideration in another way justifying the use of FLS-T2. The first is the different expert opinions of health risks and the second is uncertainty in the estimation of exposure time to radiation (tab. 2 and 3). When these two

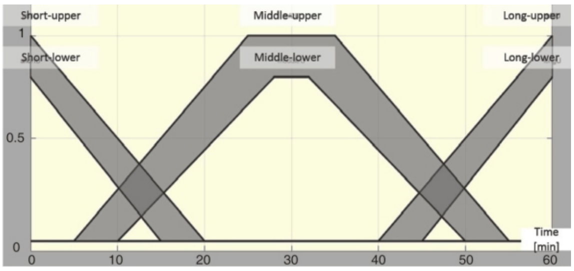

Figure 11. Exposure time – blurred membership function (type 2)

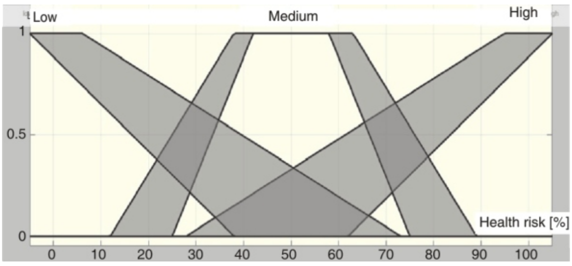

Figure 12. Health risk – blurred membership function (type 2)

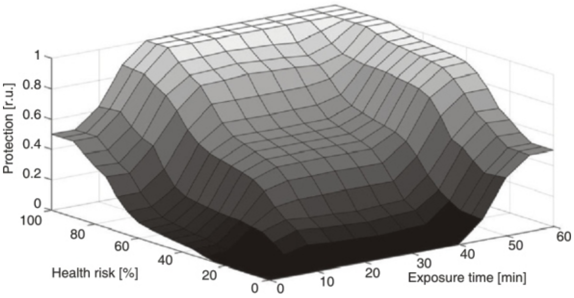

Figure 13. Need for protection (input perimeters belong to Fuzzy set I)

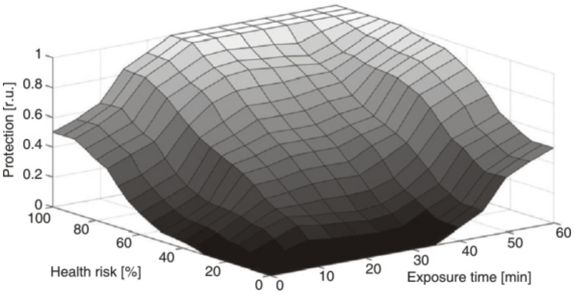

Figure 14. Need for protection (input perimeters belong to Fuzzy set II)

cases occur simultaneously, then the better solution for the assessment of the protection need is the application of FLS-T2.

Testing and validation based in FLS-Type2 were done for two fuzzy sets to investigate their parameters influence. The both fuzzy sets (tab. 2 – Fuzzy Set I and tab. 3 – Fuzzy Set II) are based on realistic measurement scenarios but with different expert opinions and different estimated exposure time.

Figure 13 shows the result of the application of FLS-T2 when the input parameters (figs. 11 and 12) contain uncertainties resulting from an expert's disagreement about the health risk assessment and the assessment of the hazard, in relation to the exposure time. Because the membership functions of a FLS -T2 are fuzzy, that is, have an FOU (blurred MF), they have more design degrees of freedom; hence, they have a greater potential to better model and handle both of these measurement uncertainties. Protection need is represented by relative unit: 0 – protection is not required; 0.5 – additional analysis is required; 1 – protection is necessary (see tab. 2).

Table 3 and fig. 14 show the result of the application of FLS-T2 with different input parameters (different FOA). There are insignificant differences in the central part of the graphics.

CONCLUSIONS

This paper proposes a new FMA, developed with the aim to combine the advantages of fuzzy logic with the advantages of improved measurement methods for measuring EMF. The main goal was to develop a robust and comprehensive algorithm, based on the theory of fuzzy logic that can be used for measuring of EMF and for the assessment of their impact on human health.

In order to facilitate the development of the fuzzy algorithm, it was first necessary to develop an auxiliary algorithm, a so-called *pathway*, required to design the EMF measuring procedure, conduct comprehensive analysis, draw conclusions and propose measures for protection.

Special attention was awarded to the development of the comprehensive FMA, aimed at consolidating and automating all measurement procedures for measuring electric and magnetic fields.

Two types of fuzzy logic systems were considered (FLS Type-1 and FLS Type-2) and then applied. When we use only the measuring results of EMF and international standards, it is sufficient to apply FLS-T1 in the FMA. However, it is often necessary to take into account the differences of expert opinions about health risk and exposure time. In that case, it is necessary to use Type-2 fuzzy sets and their corresponding membership functions. There are at least two reasons for considering the applications of FLS Type-2. The first reason is the uncertainty in measurement and the second is the difference in expert opinions pertaining to fuzzy rules.

The second part of the paper discusses the validation of the proposed FMA that was carried out using appropriate software (MATLAB), actual limits obtained from the international EMF standards and the difference in expert opinions.

The proposed algorithm can be easily used in any EMF frequency range, such as the range of 5 G mobile network with its radiation spectrum of 6 GHz to 100 GHz.

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AUTHORS' CONTRIBUTIONS

Decision making and FMAbased on fuzzy logic systems were made by S. D. Milić while the assessment of the impact of electromagnetic fields on human health was made by B. D. Vulević. The FMA testing and validation were carried out by S. D. Milić and Dj. M. Stojić. All the authors participated in the discussion of the results presented in the paper. Dj. M. Stojić and B. D. Vulević checked the manuscript and added corrections.

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Саша Д. МИЛИЋ, Бранислав Д. ВУЛЕВИЋ, Ђорђе М. СТОЈИЋ

ФАЗИ-МЕРНИ АЛГОРИТАМ ЗА ПРОЦЕНУ УТИЦАЈА ЕЛЕКТРОМАГНЕТНОГ ЗРАЧЕЊА НА ЉУДСКО ЗДРАВЉЕ

У овом раду представљен је фази-мерни алгоритам за процену утицаја електромагнетских поља на људско здравље. Алгоритам је развијен са циљем да обједини сложене и разноврсне методологије мерења, стандарде и фази логичку контролу у јединствену свеобухватну методологију за процену утицаја електромагнетних поља на људе. Алгоритам треба да омогући аутоматску процену вишеструких критеријума на основу резултата мерења, постојећих стандарда, смерница и препорука, како би се избегла потенцијална субјективност и различит приступ у процени. У ту сврху смо анализирали две класе фази система (тип-1 и тип-2) и развили графички модел намењен сценаријима у којима се мишљења експерата разликују и где та разлика може значајно да утиче на процену. Фази модел је развијен на принципу предложеног алгоритма, а као резултат се добила јединствена процедура за процену утицаја свих типова електромагнетских поља на људско здравље.

Кључне речи: мерење елекшромагнешског йоља, људско здравље, фази мерни алгоришам, фази логички сисшем