MEASUREMENT PROCEDURE FOR ELECTROMAGNETIC FIELDS OF RADAR SYSTEMS, USING A SPECTRUM ANALYZER APPARATUS

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Abstract

The radiofrequency (RF) and microwave (MW) emitting devices are used in many human activities and their application is continuously increasing. For this reason, the problem of evaluating their potential hazards to which people are generally exposed is of some concern, both for professional people, and for the general public. In the present report, the authors describe a measurement procedure, developed for the evaluation of electromagnetic fields produced by and around radar systems. By means of the developed measurement method the density power has been evaluated, using a spectrum recorder analyzer with the following extra-components: standard receiving antenna, attenuation nets, plotter.
The measurements have been carried out around many radar systems and the results have been compared with those obtained with other measurement systems and methods.

Measurement Method around Radar Systems

By means of the spectrum analyzer it is possible to visualize on the cathode ray tube the emitted electromagnetic signals, decomposed in their main components; the measurements provide the values of absolute or relative level (in dB). If the input signal is modulated, like the radar signal, the power level measured is not an absolute one, because the input electromagnetic energy is not a monochromatic and can not be thorougly detected by the spectrum analyzer. However the numerical value of input peak power reduction factor is given on the basis of the selected attenuation circuits and therefore it is possible to calculate the exact value of input power. Furthermore the use of spectrum analyzer makes measurement possible without stopping the emitting antenna in the direction of the measurement instrument. These measurement conditions represent the real operation conditions and make any correction unnecessary for the rotating factor or radiation exposure. This measurement procedure uses a spectrum analyzer mod. HP 853A/HP8559A, with the standard receiving antennas Singer mod. 93490-1 and 93491-2; the frequency range work is 500 MHz - 3 GHz, for input power values until 500 kW, if the set is arranged with suitable attenuation nets.

The measurement method proceeds as follows:

i) a calculation of the power density expected around the source and based on the characteristics of the emitting device;

ii) an investigation of the environment around the source;
iii) a choice of suitable measurement set, in relation to emitting device characteristics and the previous results;
iv) a monitoring program and the subsequent data recording on the plotter;
v) data evaluation

Before starting the monitoring program, all available information about the emitting source characteristics should be obtained, and at least the following: system operating frequency; peak/medium power; pulse width (PW), if any; pulse repetition frequency (PRF), if any; antenna gain; radiating antenna dimensions; beam width (BW); scan or rotation rate, if any; distance between the radiating antenna and the ground.

Estimated Value

To select the best measurement set, before starting the monitoring program, it is necessary to calculate the expected power density values in the measuring points. These values must be evaluated at a given distance from the source by means of:
- transmission power;
- radiating antenna gain;
- radar beam amplitude.

The estimated power density value represents the maximum power density at the centre of the main antenna lobe, in the given measurement point. This value is generally greater than the measured value, because the monitoring points are located, almost always, under the centre of the main lobe.

Environmental Investigation

All the available information about the geometrical and geographical characteristics of the site around the radar system should be obtained in order to ascertain if the radiation meets along its pattern metallic conducting structures or reflecting surfaces (for example mountains), and so on. These obstacles in fact may produce secondary fields whose intensity could add to that of main electromagnetic fields, leading to points of the site, where the field intensity could be very high. This investigation is important for personnel protection purpose.

Measurement Equipment Selection

The main items needed for selecting the measurement array are:
- distance between the survey points and the source must be greater than ten meters (far field conditions);
- radiating lobe corner at least 3 degrees above the ground;
- rotating antenna.

The evaluation of the power density allows, at the first stage, to estimate the expected power density values in the survey points, and moreover to select the suitable receiving antennas and the spectrum analyzer attenuation arrays. With the above mentioned receiving standard antenna it is possible to detect density for estimated values less than 831 mW/cm^2. For power density values greater than above this value, in the same frequency range, the spectrum analyzer has to be arranged with suitable attenuation arrays and located at a safety distance from the radiation source. The values measured with this method have been compared with the data gathered using other different measurement devices, like power meter and broadband instrumentation (NARDA 8616 system). There is a very important difference between these methodologies. A spectrum analyzer provides measurements in real working condition of the radiating system (rotanting antenna); in the other cases the antenna must be stopped and the measured values are not those really present in the working condition, and represent the maximum value of power density. This is a real working condition only in very few cases (for example during radiating system maintenance program). The power meter is equipped with bolometric interchangeable devices, which, in relation to the frequency and input power range, allow the detection and the measurement of power density values up to 200 kW/cm^2.

Monitoring Program

As the radiating system is rotating during the monitoring program, the spectrum analyzer monitor shows the maximum electromagnetic field level, when the radiating antenna is oriented towards the operator. This maximum value is recorded (on the plotter), and other values are detected in all selected measurement points. These data represent the relative power level in dBm, while the absolute values of density power are obtained through suitable conversion tables, taking into account the following parameters:
- antenna factor;
- desensitation factors;
- pulse repetition frequency (PRF);
- pulse width;
- attenuation factors of the nets.

The methodology has been verified on a great number of radar systems and have been compared with the data obtained, using other methods. The results have always been compatible.
In Table 1 results obtained around radar systems, using different measurement methodologies are shown. The same values are compared with the theoretic expected values in the same monitoring points.
In Table 2 the results obtained on laboratory radar system are shown. In this case the different measurement conditions and the secondary lobe emissions have also been evaluated; the measurements have been carried out with and without ecosorb surface, in order to take into account the real operation conditions in the effective workplaces. In this case power density values have not been estimated, because they are relative to the emission, due to the main antenna lobe, while measurements have been carried out in relation to the secondary emission lobes.

Conclusions

The obtained values during various monitoring programs around many and different radar systems confirm the validity of the the methodology, also because it allows to carry out the measurements in the real operating system condition, which are the real exposure conditions for the operators.

Table 1 – Fields Measured around Radar Systems

Plant Characteristics		Measurement Points: H_t Above the Ground (m)	Measurement Points: Distance from the Plant (m)	Estimated Power Density on the Antenna Axis (mW/cm²)	Measured Power Density (*) (mW/cm²): NARDA 8616 (Probe 8623b)	Measured Power Density (*): POWER METER (HP432-HP478 HORN SINGER 93491-2)	Measured Power Density (*): SPECTRUM ANALYZER (HP853/A-HP8559/A HORN SINGER 93491-2 PLOTTER HP7470/A)
1	P_p = 500 KW	1	20	0,06	0 (f)	0,15 (f)	0,186 (f) 83×10^{-6} (r)
	F = 1,3 GHz	4	35	0,02	3 (f)	2 (f)	5,88 (f) $2,94 \times 10^{-3}$ (r)
2	P_p = 1,8 MW	39,6	2725	$28,6 \times 10^{-6}$	0 (f)	$2,34 \times 10^{-3}$ (f)	$1,8 \times 10^{-3}$ (f) $0,452 \times 10^{-6}$ (r)
	F = 1,3GHz	2	50	0,085	0 (r)	=	$13,2 \times 10^{-3}$ (f) $3,3 \times 10^{-6}$ (r)

*
.r = rotating antenna
.f = standing antenna towards the measurement instrument.
.All the values have been obtained taking into account the suitable correction factors.

Table 2 – Laboratory Radar System

PLANT CHARACTERISTICS: P_p = 180 ÷ 220 KW F = 9,4 GHz

Measurement Point: H_t Above the Ground (m)	Measurement Point: Distance from the Plant (m)	Measured Power Density (*) without Ecosorb Surface (mW/cm²): NARDA 8616 (Probe 8623 b)	POWER METER (HP432-HP487 HORN-SINGER 93491-2)	SPECTRUM ANALYZER (HP853/A-HP8559/A HORN SINGER 93491-2 PLOTTER HP7470/A)	Measured Power Density (*) with Ecosorb Surface (mW/cm²): NARDA 8616 (Probe 8623 b)	POWER METER (HP432-HP478 HORN SINGER 93491-2)	SPECTRUM ANALYZER (HP853/A-HP8559/A HORN SINGER 93491-2 PLOTTER HP7470/A)
0,90	0,50	185×10^{-3}	100×10^{-3}	74×10^{-3}	555×10^{-3}	150×10^{-3}	74×10^{-3}
1,70	0,50	423×10^{-3}	225×10^{-3}	93×10^{-3}	925×10^{-3}	280×10^{-3}	93×10^{-3}
0,90	2	116×10^{-3}	29×10^{-3}	23×10^{-3}	231×10^{-3}	125×10^{-3}	29×10^{-3}
1,70	2	185×10^{-3}	40×10^{-3}	29×10^{-3}	462×10^{-3}	125×10^{-3}	145×10^{-3}
0,90	3	N.R.	$6,2 \times 10^{-3}$	930×10^{-6}	N.R.	$7,9 \times 10^{-3}$	930×10^{-6}
1,70	3	N.R.	N.R.	$2,9 \times 10^{-3}$	46×10^{-3}	$9,9 \times 10^{-3}$	$4,7 \times 10^{-3}$

* All the values have been obtained taking into account the suitable correction factors.