MEASUREMENT OF ELECTROMAGNETIC FIELDS EMITTED BY RADAR SYSTEMS USING A BROADBAND SAMPLER MEASUREMENT SYSTEM IN ENVIRONMENTAL SURVEILLANCE CAMPAIGN

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SUMMARY

Microrad has developed an innovative system which measures electromagnetic pulse field levels by way of a broadband probe combined with an envelope sampler.
This measurement system is capable of demodulating a pulsed signal and adequately sampling it for the purpose of correctly representing it in a time domain thus allowing the acquisition of the technical characteristics of the radar as indicated in appendix B of the Italian Norm CEI 211-7 and as required by environmental surveillance campaigns. The measurement equipment is based on probes which are composed of a resistive dipole capable of reaching response times of less than one microsecond. The demodulated signal is then transmitted to the envelope sampler which is connected to a personal computer or tablet by way of a fibre optic cable. Data received by the PC tablet is then processed using a specific software application already installed on the PC /Tablet.
This paper describes the results of the survey carried out on specific air traffic control radars (radar ATCR-33S). The objective of the study is to establish the congruity between the measurements taken by this system and measurements taken using traditional narrow band instruments (spectrum analyser and horn antenna)
The measurements which were conducted in parallel have allowed us to evaluate the accuracy and effectiveness of this new type of instrument.

1. INTRODUCTION

The measurement system briefly described in the summary was developed as a prototype by Microrad and is currently in a test phase.
In order to evaluate its reliability a survey was carried out jointly between ISPRA and Microrad: in the sites where survey took place the readings / measurements were taken in parallel using this instrument and traditional narrow band instruments namely a spectrum analyser and horn antenna.
The following section describes the new measurement system, the survey carried out to evaluate its reliability and presents the findings recorded.

2. DESCRIPTION OF THE NEW MEASUREMENT SYSTEM COMPOSED OF BROADBAND PROBES AND AN ENVELOPE SAMPLER

This new measurement solution for pulsed signals has been developed by Microrad in accordance with appendix B Norma CEI 211-7 [1], integrating the typical characteristics of a wide band probe with those of an envelope sampler. The system includes a personal computer/tablet which runs a specific software application and is connected to the sampler by way of a fibre optic cable.
The primary objective of Microrad is to offer an agile/ measurement solution which offers the possibility of post processing the data which can be used for the characterisation and evaluation of the radar emissions.
The measurement system described in this article is basically composed of a wideband probe with a resistive dipole and a diode detector used in conjunction with an envelope sampler and is able to operate in a time domain even though it has physical dimensions, weight characteristics and operating times similar to those of wide band instruments.

Technical characteristics of the probe used (in the study)[1]:

- Frequency band: 2 – 3 GHz
- Flatness of frequency response: ± 0,5 dB
- Response time: 1 μs
- Sensitivity: 0,2 V/m
- Dynamic: 60 dB

[1] In the near future further development of interchangeable directional and multidirectional probes with different characteristics for passive and dynamic bands is planned.

Main characteristics of envelope samplers:

- Analogue/digital conversion and numeric processing of envelope signals in three possible time resolutions (T) or window acquisition window width (W) selected from the application software:
  T = 200 µs, W = 13,1 s
  T = 10 µs, W = 655,3 ms
  T = 0,5 µs, W = 32,7 ms
- Power supply : Li-Ion battery
- Communications with pc/tablet via fibre optic

Main features of the application software:

- Representation of the enveloped signal evolution in the time domain, setting of acquisition trigger, marker insertion, data and image export.

The following figure shows a block diagram of the measurement system described above.

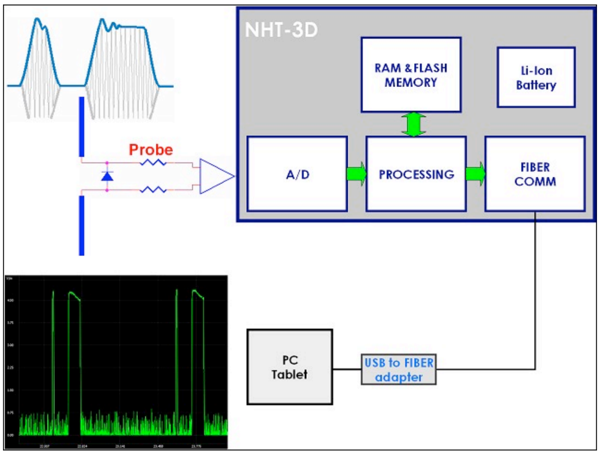


Fig. 1. Block diagram of wideband sampler measurement system.

3. SURVEY DESCRIPTION

During the survey which was jointly carried out by ISPRA-Microrad the results were composed from two separate sessions in which readings were taken in the immediate vicinity of Firenze Peretola airport and Roma Fiumicino airport respectively. Both airports were using an ATCR-33S radar for air traffic control.

The measurements were taken on 29th April 2013 at Firenze Peretola Airport (Fig. 2) and on 13th May 2013 at Roma Fiumicino airport (Fig. 3).
The images shown in the following figures show the position of the radar and the point from which the readings were taken (in both cases indicated by the letter P).
The distance between the radar and measurement point was calculated as 1116 m in the case of Peretola and 508 m in the case of Fiumicino..
In each of the survey areas the readings were taken first using the narrow band instrument and then using the broadband sampler measurement system. In each of the situations the measurements were carried out positioning the antennas at a height of 1,5 m from the ground.

With regard to the narrow band analysis, the measurements were taken in compliance with appendix B Norma CEI 211-7 [1], following the CNR-IFAC procedure described in [2].

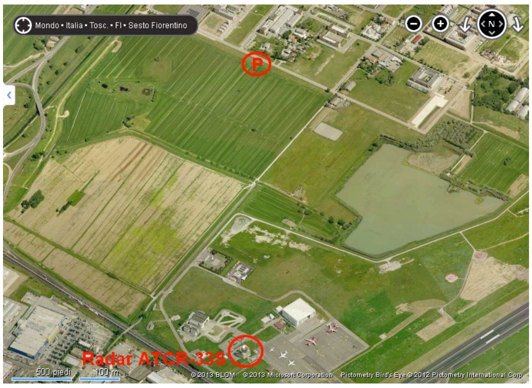


Fig. 2. Aerial photo of survey site being measured – FI Peretola

Fig. 3. Aerial photo of survey site being measured – RM Fiumicino

The following figures show the two measurement instruments utilised during the study.

Detailed composition of measurement system:

- Narrow band measurement system
  - horn antenna ETS mod. 3115 (750 MHz – 18 GHz)
  - coaxial cable Suhner mod. Sucoflex 102A
  - Rohde&Schwarz spectrum analyzer mod. FSP30 (9 kHz – 30 GHz)
- Envelope sampler measurement instrument
  - Microrad directional broadband probe with resistive dipole and diode detector mod. RP01 (2 – 3GHz)
  - Microrad high dynamic envelope sampler Microrad mod. NHT-3DR
  - fibre optical cable
  - optical /USB converter
  - portable personal computer/ notebook equipped with Microrad mod. Waves application software

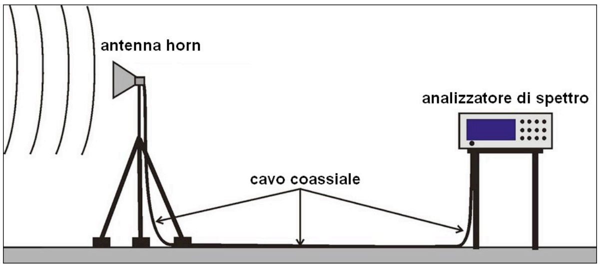


Fig. 4. Narrow band measurement chain

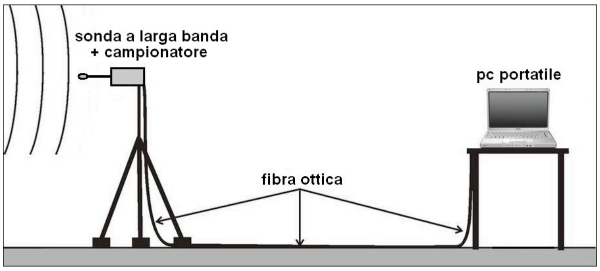


Fig. 5. Wide band envelope sampler measurement chain

4. RESULTS

The following results are presented according to the instrument utilised in each of the two survey sites mentioned in the previous paragraph. All useful (and relevant) information required to define the electromagnetic emissions from the radar source being examined was measured.

1) Firenze Peretola (29/04/2013)

Fig. 6. View of Firenze Peretola airport radar

- Narrow band measurement chain
  - Radar frequency functions:
    The radar operates on three different frequencies
    f_1 = 2734,4 MHz
    f_2 = 2815,2 MHz
    f_3 = 2855,2 MHz
  - Antenna rotation time :
    T_{rot} = 3,78 s
  - Illumination time :
    T_{ill} = 14,8 ms
  - Impulse repetition time:
    T_{rip} = 1,11 ms
  - Pulse duration:
    The radar functions by using a sequence of pulses composed of long pulses and short pulses which respectively last
    τ_1 e τ_2, are [2]:
    τ_1 = 98 µs
    τ_2 = 9,9 µs
  - Peak value of electrical field:
    E_{peak} = 2,3 V/m
  - Average value of electric field medio[3]:

$$E_{average} = E_{peak} \cdot \sqrt{\frac{\tau}{T_{rip}}} \cdot \sqrt{\frac{T_{ill}}{T_{rot}}} = 45 \text{ mV/m}$$

- Broadband sampler measurement system
  - Antenna rotation period:
    T_{rot} = 3,8 s
  - Illumination period:
    T_{ill} = 14 ms
  - Pulse repetition time:
    T_{rip} = 1,1 ms
  - Pulse duration:
    The radar operates using a sequence of pulses composed of long pulses and short pulses which respectively last
    τ_1 e τ_2, are (see note 2):
    τ_1 = 100 µs
    τ_2 = 10 µs
  - Peak electric field value:
    E_{peak} = 2,65 V/m
  - Average electric field value:

$$E_{average} = E_{peak} \cdot \sqrt{\frac{\tau}{T_{rip}}} \cdot \sqrt{\frac{T_{ill}}{T_{rot}}} = 51 \text{ mV/m}$$

2) Roma Fiumicino (13/05/2013)

[2] For the purposes of calculating the duty cycle and the average value of the electric field, the couple of pulses lasting τ_1 e τ_2 is equivalent to a single impulse of length $\tau = \tau_1+\tau_2$.

[3] For technical and logistical reasons it was not possible to calculate the average value of the electric field using the *Channel Power* mode". The calculation was therefore made using the peak field value and the technical specifications of the radar which were obtained in the time domain.

- Narrow band measurement chain
- Narrowrband measurement system
  - Radar frequency function:
    f = 2805 MHz
  - Antenna rotation time:
    T_{rot} = 3,82 s
  - Illumination time:
    T_{ill} = 13,2 ms
  - Impulse repetition time:
    T_{rip} = 1,09 ms
  - Pulse duration:
    The radar operates using a sequence of pulses composed of long pulses and short pulses which respectively last
    τ_1 e τ_2, are (see note 2):
    τ_1 = 100 µs
    τ_2 = 9,6 µs
  - Peak electric field value:
    E_{peak} = 5,13 V/m
  - Average electric field value [4]:

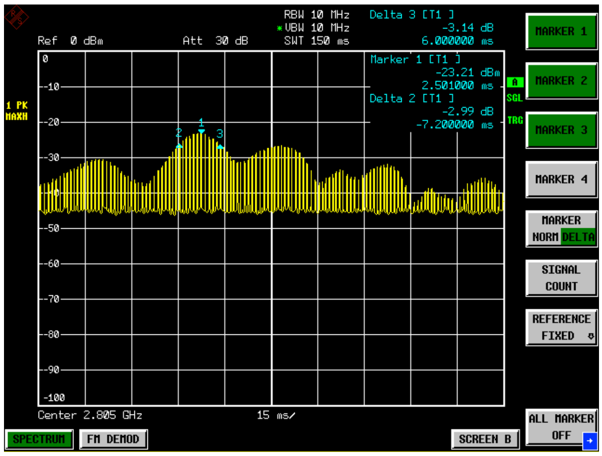
$$E_{average} = E_{peak} \cdot \sqrt{\frac{\tau}{T_{rip}}} \cdot \sqrt{\frac{T_{ill}}{T_{rot}}} = 0{,}1 \text{ V/m}$$

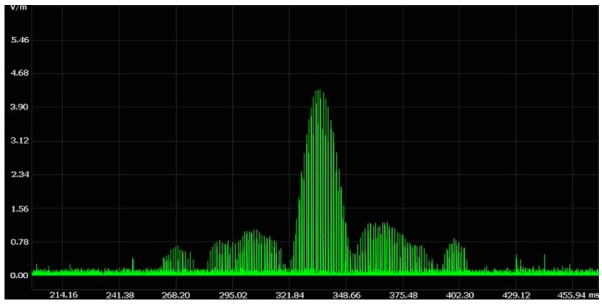
$E_{medio\text{-}CHPWR}$ = 0,2 V/m

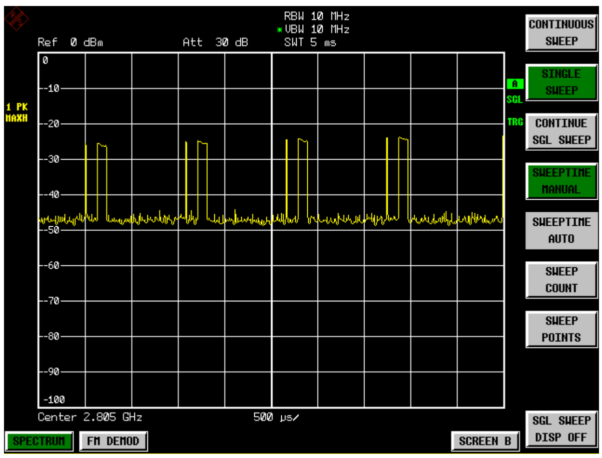
- Broadband sampler measurement system
  - Antenna rotation time:
    T_{rot} = 3,82 s
  - Illumination time:
    T_{ill} = 12,9 ms
  - Pulse repetition time:
    T_{rip} = 1,09 ms
  - Pulse duration:
    The radar operates using a sequence of pulses composed of long pulses and short pulses which respectively last
    τ_1 e τ_2, are (see note 2):
    τ_1 = 100 µs
    τ_2 = 10,1 µs
  - Peak electric field value:
    E_{peak} = 5,11 V/m
  - Average electric field value:

$$E_{average} = E_{peak} \cdot \sqrt{\frac{\tau}{T_{rip}}} \cdot \sqrt{\frac{T_{ill}}{T_{rot}}} = 0{,}09 \text{ V/m}$$

The following screenshots represent different moments during the measurement process while utilising the two instrument chains (the images alternate between spectrum analyser and the "Waves" software application).







[4] In this case the average value of the electric field has been calculated both in the frequency domain via the "Channel Power" mode ($E_{average\ -CHPWR}$), and also by starting with the maximum field value ed utilising the technical characteristics of the radar obtained in the time domain. ($E_{average}$). It should be noted that the two values do not coincide and this depends on the higher uncertainty with which the the technical characteristics of the radar in the time domain are acquired.

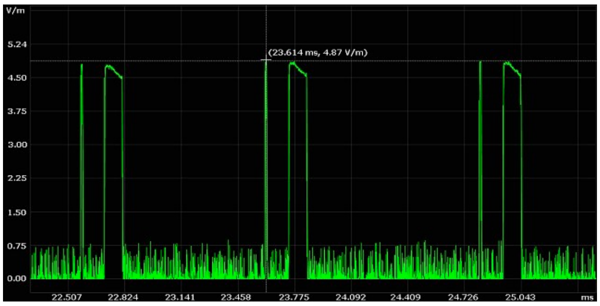


Fig. 8*. Screenshots obtained from the measurement instruments*

5. CONCLUSIONS

The results indicated in the previous paragraph show a high level of congruence between the readings obtained from the narrow band measurement instruments and those of the Microrad broadband envelope sampler measurement system from Microrad. The difference in the technical characteristics of the radar in the time domain is less than 5% while the differences in the peak value of the electric field in both cases Firenze Peretola and Roma Fiumicino, are 1,2 dB and 0,03 dB respectively.
Differences in the average value of the electric fields are not taken in to consideration as this value for both measurement systems was derived from a formula whose entry parameters are the peak electric field value and the technical characteristics of the radar in the time domain.[5].
From what has been said above, one can say that in the analysis of signals emitted from radar systems such as those examined in the survey, the broadband envelope sampler measurement system can be considered a valid alternative to traditional narrow band measurement systems.

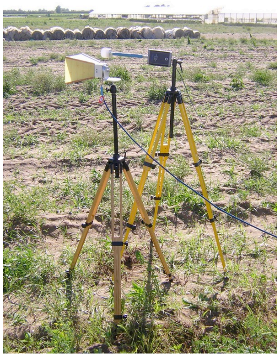


Fig. 9*. A view of the antennas of both systems used in parallel during the survey.*

[5] In reality, in the case of the narrowband measurement chain, the average value in the survey carried out at Roma Fiumicino was obtained also by measurements of the frequency domain in “Channel Power” mode. Refer to note 4 for the reasons regarding the difference in the calculation of the average electric field value in the two different modes (“Channel Power” in the frequency domain and a mathematical formula which utilises the technical characteristics of the radar in the time domain).

The following is a list of the strengths and weaknesses of this equipment observed during the survey activity.

Strengths:
- considerable reduction in time required to perform analysis compared to that of the instrument chain which includes the spectrum analyser;
- compact and light as a measurement system;
- Li-Ion battery which assures an operating time in excess of 5 hours;
- complete isolation between the instrument and pc/tablet thanks to the fibre optic connection.

Weaknesses:
- impossible to obtain the radar frequency ;
- less sensitive than a spectrum analyser.

In the coming months further measurement tests are expected to evaluate the response of the Microrad system to radar signals different to those which were examined in this survey. Microrad is currently developing new directional and omnidirectional probes which will be capable of covering other portions of the electromagnetic spectrum of interest in radar analysis. It is also expected that there will be an increase in the sampling frequency of the analogue / digital converter (A/D) of the envelope sampler to capture pulses with durations of less than one microsecond.

6. BIBLIOGRAPHY

[1] “*Guide for the measurement and the evaluation of electromagnetic fields in the frequency range 10 kHz - 300 GHz with reference to the human exposure Appendix B: Measurements and evaluation of the electromagnetic fields generated by radar systems*”, first ed., January 2008.

[2] M. Bini, A. Ignesti, C. Riminesi: “*Procedura per la misura di Campi EM emessi da impianti Radar utilizzabile in campagne di Sorveglianza Fisica Ambientale*”, IFAC-CNR Technical, Scientific and Research Reports (ISSN 2035-5831), Vol.2, N.65-3 (2010), CNR-IFAC-TR-08/009, Firenze, agosto 2009.

[3] M. Bini, A. Ignesti, C. Riminesi: “*Misura del campo EM emesso dal Radar Primario ATCR-33S installato presso l'aeroporto di Firenze-Peretola*”, IFAC-CNR Technical, Scientific and Research Reports (ISSN 2035-5831), Vol.2, N.65-5 (2010), CNR-IFAC-TR-01/010, Firenze, gennaio 2010.