Continuous Revolution Method for Antenna Radiation Pattern Measurements

Miroslav Gechev [1], Kliment Angelov [2], Boyan Kehayov [3], Sava Denev [4], and Svetoslav Kremenski [5]

Abstract – **In this paper a new method for antenna radiation pattern measurements has been presented. An idea for continuously rotating the antenna and mathematical processing of the collected data is described. That gives the opportunity for minimizing the error and simplifying the measurement techniques. The results can be used in case of automatized low-cost antenna tests with improved accuracy level.**

Keywords – **Radiation pattern, Antenna measurements, Improved accuracy.**

I. Introduction

The radiocommunications, and more specifically the use of electromagnetic waves (EMWs) for the transmission of information, are an integral part of the everyday life of the modern person. The transmission and reception of EMWs is accomplished by using antennas, which have requirements for specific characteristics and parameters, which in turn are based on the specific use of the antenna in the various communication systems. Many analytical and simulation methods are used in the construction of the antennas, but still the need for experimental measurements exist. This is a fact, on one hand, due to the need of meeting and/or exceeding the specific technical requirements, and on the other hand, in order to create a better living environment for the population by reducing the unwanted electromagnetic radiation.

A key characteristic of each antenna is its radiation pattern (RP) [1] [2]. It shows how the antenna distributes spatially its transmission and/or reception of EMWs in/from the different directions. There are two types of RPs – directional and omnidirectional, and in some cases a more specific shape of the RP is desirable (e.g. in cell phones it is desirable to reduce the radiation in the direction of the head of the user [3]). The experimental determination of the RP is connected to the requirement for different spatial orientation of the antenna under test (AUT) for the specific equipment used for the measurement. Two degrees of freedom (rotation in two orthogonal axes) are required as well, but still in most of the cases a rotation in only one axis could be used. After measuring the RP on the first plane, the AUT is positioned orthogonally to the first position (plane) and a measurement of the RP on the second plane is performed. Interruption and manual set of the spatial position of the AUT leads to errors, avoiding which is especially critical when testing and measuring antennas that are highly directional and with narrow beams on its RP.

In this paper a method for automated measurement of antennas' RPs is proposed – it is based on rotation on one axis with multiple repetitions of spins and subsequent mathematical processing of the reported results in order to achieve higher measurement accuracy.

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II. Description of the Problem

A. Radiation Pattern Measurements

Problems associated with experimental tests of antennas are examined in numerous scientific studies, where determining the RP is one of the most commonly discussed issues [4][5][6][7]. Table I shows the basic criteria for classification of the measurements of RPs during the study of an antenna. Usually when conducting low-budget experiments with a relatively low degree of precision, stands with one degree of freedom are used – the rotation is on one axis only. Also, in such cases the spatial orientation of the antenna under test is determined manually and the measurements are conducted in outdoor conditions, rather than in an anechoic chamber that reduces any disruptive and/or reflected signals.

When it is necessary to carry out more high-tech measurements, which aim to increase the accuracy of the results, more complex mechanical positioning stands with two degrees of freedom are used (the rotation is on two orthogonal axes).

Also – it is very much appropriate to conduct the experimental measurements in an anechoic chamber. This would increase the accuracy of the test results, but it must be noted that the economic cost of such facility is very high and it depends on the working frequency bands the chamber is aimed to be applicable for.

The use of anechoic chamber is economically justified only when used regularly.

TABLE I
RADIATION PATTERN MEASURING CLASSIFICATION

Number of Rotation Axes	One Axis
	Two Axes
Measuring Distance	Near Field Measurements
	Far Field Measurements
Position Angle Settings	Manual
	Mechanically Automatized
Antenna Mode	Transmitting
	Receiving
Minimization of the Interference	Free Space Measurements
	Anechoic Chamber

In terms of the distance of measurement ***d*** two cases can be considered [5] – if the measurements are carried out in the near field of the antenna or if carried in the antenna's far field. In the former case a more complex measurement equipment is needed but based on the obtained experimental results and with the help of analytical methods the far field radiation of the antenna can be determined [6][7].

B. Theoretical Basis

Based on the overview of the methods for measuring the antenna parameters, it becomes clear that it is more relevant to seek accomplishment of a smaller error when using the more simpler and cost-efficient testing techniques. In the theory, in order to reduce the negative impact of random and sporadic errors, we resort to measurement repetitions and result averaging. In the case of experimentally determining the radiation pattern of the antenna under test, this repetition can be accomplished by repeated (multiturn) rotation of the antenna around the axis of rotation for the specific measurement. Fig. 1 shows an example scheme of the test stand based on the aforementioned concept.

If the angular velocity of rotation ω of the antenna is constant, then at a constant sampling period of the received signal a recurrent dependence would be obtained. From the data thus obtained and by making use of the mathematical analysis the analytical dependencies determining the RP based on the averaged data for each rotation period can be found.

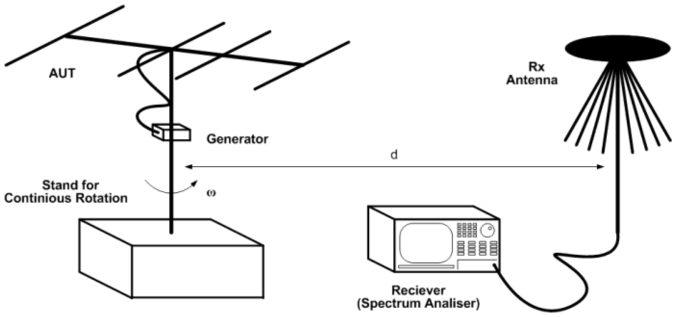

Fig. 1. Scheme of Test Stand

Another advantage of the aforementioned method is the possibility for a relative reading of the angle of the position of the AUT – θ. In the case of an absolute set of this positional angle, it is required to choose a neutral (starting) position at the beginning of the measurement in contrast to which to report the radiation in the other directions. In the proposed in this paper method, the angle θ can be reported after finding the average analytical dependence of the radiation pattern, keeping in mind the fact that its main lobe rises from the continuous rotation of the antenna with angular velocity ω. The minimal angular size in the reporting of the RP can be determined by applying the Nyquist principle at given angular velocity ω and sampling period of the received signal T_s:

$$\theta_{\min} = 12.T_s.\omega . \qquad (1)$$

In Equation (1) θ_{min} is obtained in degrees as T_s is in seconds and ω in rpm.

C. Test Implementation

Based on the idea proposed in this paper a simplified measurement setup was built. The goal is to verify the reliability of the proposed method by using repetitive/multiturn measurement of the radiation pattern of a simple Yagi-Uda antenna and after the accumulation of enough data a mathematical analysis can be applied. The resulting averaged RP from the test then can be compared to the RP obtained by the simulation in order to determine the accuracy of the measurement.

Table II shows the implementation characteristics of the main elements of the test stand. The spectrum analyser GW Instek [8] model GSP-830 is used as a measuring receiver, which with the help of specialized proprietary software developed by the manufacturer allows for the data of the spectral image at specific intervals to be stored in the memory of a personal computer.

During the measurement itself the requirement to perform the measurement in the far field of the source is fulfilled [9][10]:

$$d > \frac{2.D^2}{\lambda}, \qquad (2)$$

where D shows the maximal dimension of the antenna as λ shows the working wavelength.

TABLE II
TEST IMPLEMENTATION CHARACTERISTICS

AUT	Type	Yagi-Uda
	Number of Elements	Three
	Maximal Dimension	0,5 m
	Theoretical Directivity	7,52 dBi
Transmitter	Frequency	434 MHz
	RF Power	0 dBm
Stand for Continuous Rotation	Number of Axes	One
	Rotation Speed	~1,4 rpm
Measuring Distance		10 m
Receiving Equipment	Spectrum Analyser	GSP-830
	Receiving Antenna	Omnidirectional
	Sampling Speed	1 s^{-1}

III. RESULTS

Fig. 2 shows the received spectrum affected by the radiation of the AUT at specific point in time.

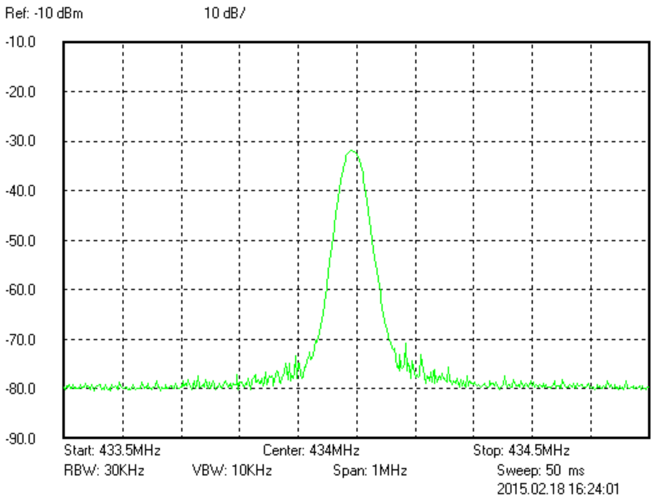

Fig. 2. Received Spectrum

Fig. 3 shows the measured change in time of the received by the spectrum analyser signal for the transmitter's transmission frequency. The shown duration of the signal covers several rotation turns of the AUT. In some of the turns more irregular changes were noticed that were caused by outside interference from various kinds. After averaging the RP by using the method of repetitive measurements, the impact of the outside interference shall be minimized.

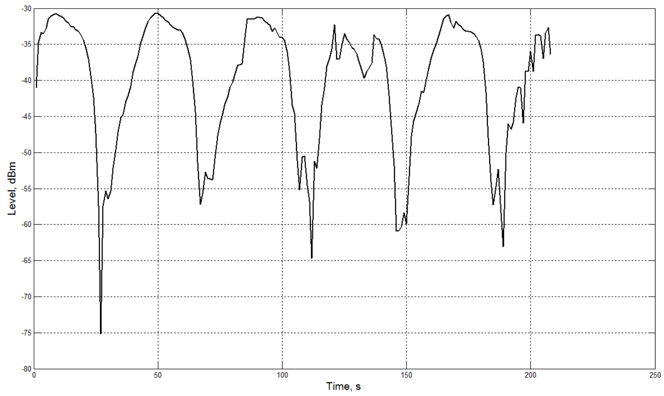

Fig. 3. Received Periodic Signal

Fig. 4 shows the averaged radiation pattern after processing the shown on Fig. 3 periodic signal using the MATLAB [11] environment.

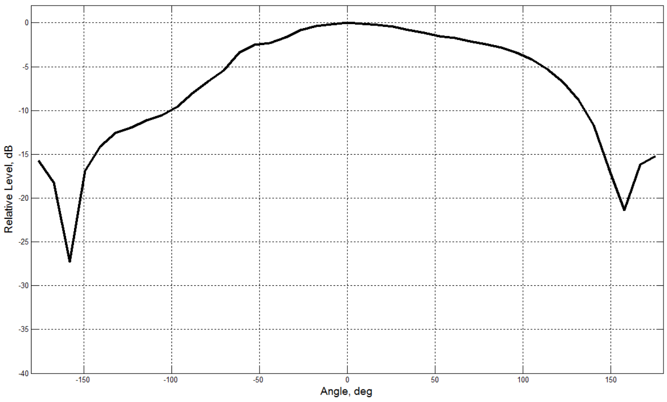

Fig. 4. Averaged Radiation Pattern

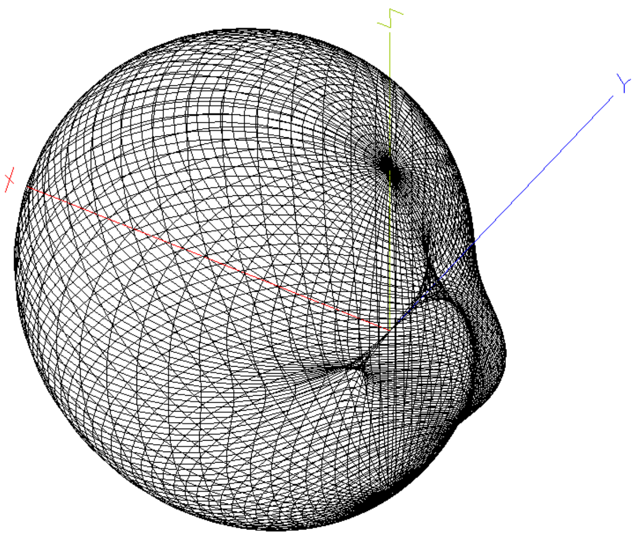

Fig. 5. Simulated 3D Radiation Pattern

Fig. 5 shows the resulting three-dimensional simulated radiation pattern of the antenna under test in free space.

The antenna's two-dimensional cross-section in the plane used in the performing of the experimental study is shown on Fig. 6.

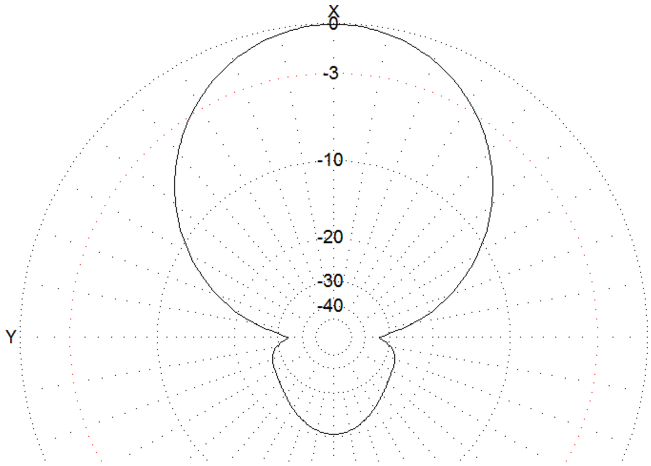

Fig. 6. Simulated 2D Radiation Pattern

Fig. 7 shows the experimentally obtained averaged radiation pattern. There can be seen the difference in the position of the directions with minimal radiation, as well as the angular width of the RP's elements. This is due to the poor isolation of the influence of the reflected signals during the implementation of the test.

In general there are significant similarities as well – the levels of backward radiation and those in the areas of minima are close. Also, the experimentally determined radiation pattern coefficient, which value is 7,57 dBi, is close to the theoretical one – 7,52 dBi. Also, there is a minimization of the interferences and it can be seen in the primary data of the measurement.

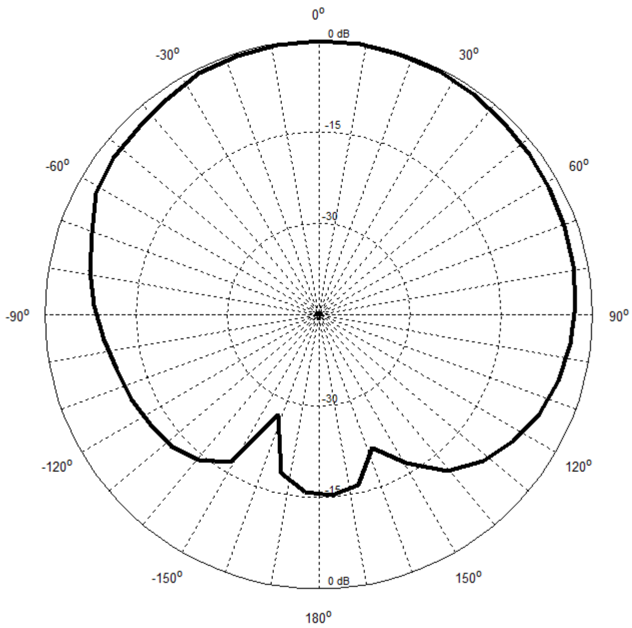

Fig. 7. Experimental Radiation Pattern in Polar Coordinates

IV. Conclusion

Based on the obtained results the following conclusions can be drawn:

- the method proposed in this paper for determining the radiation pattern and the subsequent analytical processing of the periodic data provides encouraging results for the applicability of the method in practical measurements;
- there is a minimization of interferences, seen in some of the antenna's revolutions, because of the process of mathematical processing of the collected measurement data;
- it is needed to look for additional optimizations, in order to enhance the method's accuracy.

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References

[1] Johnson R. C., Antenna Engineering Handbook, 3-rd ed., McGraw-Hill, 1993.

[2] Collin R. E.,Antennas and Radiowave Propagation, McGraw-Hill, 1985.

[3] Schiavoni A., P. Bertotto, G. Richiardi, P. Bielli, SAR Generated by Commercial Cellular Phones – Phone Modeling, Head Modeling and Measurements, IEEE Transaction on Microwave Theory and Techniques, Vol. 48, No. 11 Part: 2, pp. 2064-2071, Nov. 2000.

[4] Bhavsar V., N. Blas, H. Nguyen, A. Balandin, Measurement of Antenna Radiation Patterns, EE117 Laboratory Manual, UC-Riverside, 2000.

[5] Icheln C., Methods Measuring RF Radiation Properties of Small Antenas, Helsinki University of Technology Radio Laboratory Publications, Teknillisen korkeakoulun Radiolaboratorion julkaisuja Espoo, October, 2001.

[6] Hansen J.E., Spherical Near-Field Measurements, IEE Electromagnetic Waves Series 26, 387p, London, UK, 1988.

[7] Yaghjian A.D., An Overview of Near-Field Antenna Measurements, IEEE Transactions on Antenna and Propagation, Vol. AP-34, No. 1, pp. 30-45, Jan. 1986.

[8] www.gwinstek.com

[9] Antenna Measurement Theory, Introduction to Antenna Measurement, Reprinted with the permission of ORBIT/FR Inc., www.orbitfr.com

[10] Foegelle M. D., Antenna Pattern Measurement: Concepts and Techniques, Reprinted from Compliance Engineering, Annual Reference Guide 2002 • Copyright © 2002 Canon Communications LLC

[11] MATLAB IMAGE PROCESSING TOOLBOX. User's Guide, "The Math - Works Inc.", 2000. www.mathworks.com.