Automated Measurements with Parallel Computation of the Radiations and the Surface Waves from Patch Antennas

Chavdar Levchev[1] and Nikolay Stoyanov[2]

Abstract – **In this paper the block scheme at automated system of control the measurements with parallel computations of the information is shown. The characteristics of measurement far field and near field are examined. One of the main purposes is measure of surface waves in the microstrip antenna arrays. The functions of everyone measurement tools are discussed. The special software about these measurements is made. For example the graphics and diagrams are presented.**
Keywords – **Automated measurements, surface waves, patch antennas, far field, near field**

I. INTRODUCTION

The measurement of electromagnetic radiations realize by using concrete standards. In the last few years the measurements are automated. The antennas, the measurement instruments, amplifiers and cables are calibrated and certificated and their parameters are under permanent control [1]. The antennas under test are put on a special roll-over-azimuth positioner in the anechoic chamber for different measurements. The measurement is realized outside of anechoic chamber. In this work is given short description at automated system of control the measurements with parallel computations of the information.

II. AUTOMATED SYSTEM OF CONTROL THE MEASUREMENTS AND PARALLEL COMPUTATIONS OF THE INFORMATION

The block scheme at automated system for control of the measurements with parallel computations of the information is shown at fig. 1. The screening of the chamber together with microwave absorber can provide suitable environment. This type measurement chamber is trying to simulate the conditions of the free space. The screening reduces the noise level from the surround area and other external influences. The microwave absorbers minimize the unwanted reflected waves from the walls which have influence at the measurements. In the practice, it is easy to reach high levels of attenuation (from 80 *dB* to 140 *dB)* by screening at the interferences in the surrounding area which usually makes these interferences negligible.

The special roll-over-azimuth positioner rotates from 0° to 360° in horizontal plane and can be used for control of antenna under test (AUT) height.

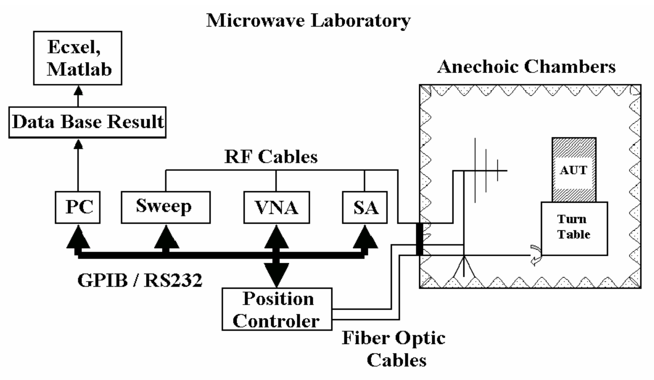

Fig. 1. Block scheme of automated system for control of the measurements

Inside the anechoic chamber, the antenna under test is put on the roll-over-azimuth positioner. In the chamber is mounting a measurement antenna over control mast which allows changing the polarization. The control of the roll-over-azimuth positioner and the mast realized by helping of positioner-controller, which one is controlled by a computer. The connection between positioner and the mast realizes by optic cables which ones together with antenna RF cables go out and go into the camera through a special panel with suitable couplings. Special software for control and treatment of the results is developed and introduced for this whole measurement process. A software fragment which control the positioner is shown at fig. 2.

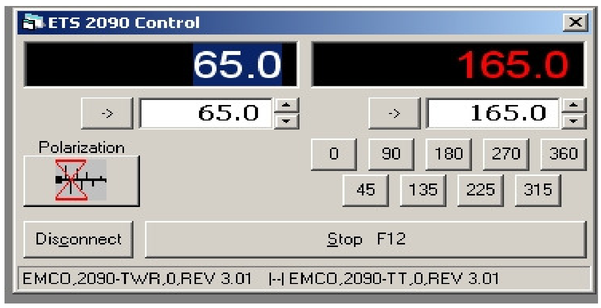

Fig. 2. Positioner Panel

Another basic element of measurement process is the measurement antenna. The antenna must be calibrated standard antenna with parameters – gain (G), antenna factor (AF), VSWR and diagram pattern. A short description of developed methods of measurement at electromagnetic radiation in anechoic chamber is shown in fig. 3.

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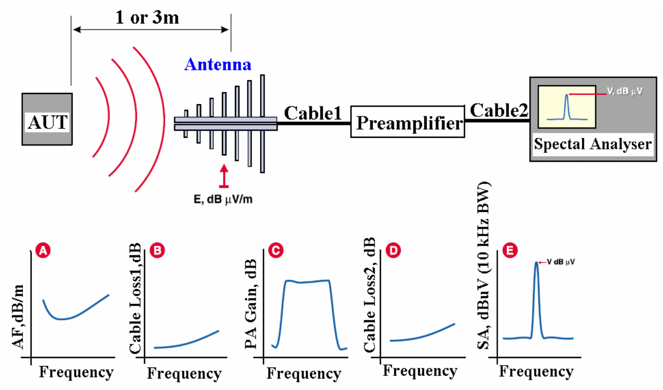

Fig. 3. Methods of measurement at electromagnetic radiation in anechoic chamber

$$E(dB\mu Vm^{-1}) = V(dB\mu V) + CL1(dB) + CL2(dB) + AF(dBm^{-1}) - PAG(dB)$$

A is an antenna factor like. The dimensions are dB/m. The antenna factor connects the voltage of antenna output with conditional power of the field around the antenna. The antenna factor is different for each frequency. B, D are corrections of the signal which are result of cable losses from attenuation and mish-mash.

C - gain of preamplifier like a frequency function,

E – the measurement value about given frequency of SA with RBW=10 kHz, VBW=3kHz In the Anechoic chamber (Fig.3) at the place of measurement antenna put the tested antenna with the known parameters. The antennas are turned directly one opposite other. The signal of the etalon antenna comes from the sweep-generator. The level of received signal at the measurement antenna is measured with spectral analyzer. After that at the place of measurement antenna is put a etalon antenna and measure her level. The levels can be measured with the spectral analyzer and with the vector network analyzer/ (VNA) also.

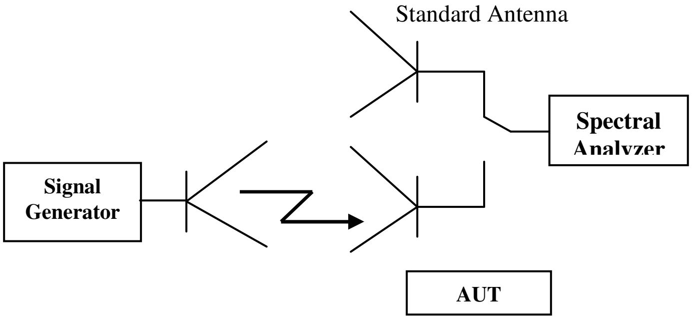

Fig. 4. Comparison between the antennas

$Gaut = L1 - L2 + C$, where Gaut is the gain of the measurement antenna (dBi), L1 – measured level of the received signal from the AUT (dB), L2 – measured level of the received signal from etalon antenna (dB), C –gain of the etalon antenna (dBi).

VSWR must be measured at the cables and the amplifiers which are used in the measurement because there are losses from mish-mash. The attenuation losses in the cables and preamplifiers gain are measured also.

All these measurements make with the VNA /vector network analyzer/ which give a chance be measured the amplitude, the frequency and the phase of (at) the different parameters at the measurement antennas. The mentioned above antenna parameters, amplifiers and cables are include in the computation algorithm about measured electromagnetic radiations. Periodically is necessary to make an examination at diagram pattern of measurement antennas. This examination can be made in the anechoic chamber where at the place of measurement antenna is put an etalon antenna for the necessary frequency diapason. The roll-over-azimuth positioner is rotating with fixed step up to 360°. The measurement is automated and special software is developed. A fragment from this software is shown at fig. 5.

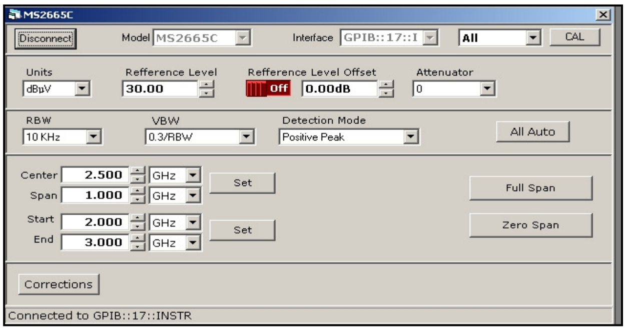

Fig. 5. Spectral Analyzer panel

The basic part in this system is the receiver. In this case this receiver is a spectral analyzer (SA) ANRITSU MS 2665C. The SA have a determine sensitivity which define the general sensitivity at the whole system[4]. SA measures the amplitude-frequency characteristics at the electromagnetic field. The measurement with SA is automated also and a fragment from this software is shown at fig. 6.

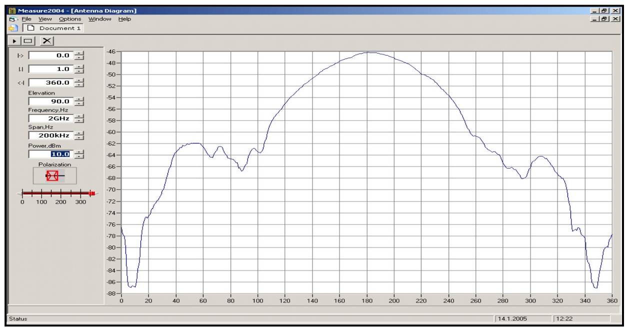

Fig. 6. Measured antenna pattern

The distance between the two antennas can be 1m or 3m and the antenna, which one must be measured, is put on the rotating table at high 0,8m.

The measurement antenna is mounted on a rotating mast and the field strength for the two polarizations, horizontal and vertical respectively, is measured. The rotation at the table is at intervals of 45°. The frequency diapasons are from 30 MHz to 15GHz in the "positive peak" mode at the spectral analyzer. The measurements are making for e two highs. The measurement and processing of the information is parallel. The measurement files are saved in the data base for the different users.

III. NEAR FIELD MEASUREMENT

The radiation field from a transmitting antenna is characterized by the complex Poynting vector **E x H*** in which **E** is the electric field and **H** is the magnetic field. Close to the antenna the Poynting vector is imaginary (reactive) and **(E, H)** decay as 1/r [5]. These two types of fields dominate in different regions in space around the antenna. Based on this characterization of the Poynting vector, can identify three major regions (Fig. 7).

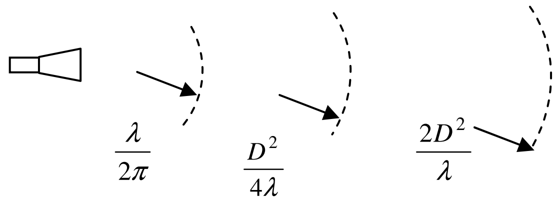

Fig. 7. Radiation regions

– *Reactive field*

This region is the space immediately surrounding the antenna. The extend of this region is $0<r<\lambda/2\pi$, where λ is the wavelength.

– *Radiating Near-Field*

Beyond the immediate neighborhood of the reactive field the radiating field begins to dominate. The extend of this region is $\lambda/2\pi<r<2D^2/\lambda$, where D is the largest dimension of the antenna. This region can be divided into two subregions. For $\lambda/2\pi<r<D^2/4\lambda$ the fields decay more rapidly than 1/r and the radiation pattern (relative angular distribution of the field) is dependent on r. For $D^2/4\lambda<r<2D^2/\lambda$ the fields decay as 1/r, but the radiation pattern is dependent on r.

– *Radiating Far-Field*

Beyond the radiating Near-Field region $r>2D^2/\lambda$ or $r>10\lambda$ (criterion for small antennas) the Poynting vector is real (only radiating fields) and has only two components in spherical coordinates (θ, φ)

IV. PLANAR SCANNING TECHNIQUE

In the planar scanning technique, a probe antenna is moved in a plane situated in front of the AUT and the received signal (amplitude and phase) is record. The position of the probe is characterized by the coordinates (x, y, z_0) in the xyz coordinate system of the AUT. During the scanning, z_0, is kept constant, while x and y are varied. The distance z_0 is approximately 3λ to avoid the sampling of the reactive energy of the AUT. The dimensions of the Near-Field scanning aperture must be large enough to accept all significant energy from the AUT. The scan dimensions, D, have to meet the criterion $D_s > D+2z_0 \tan\theta$, where D is the largest AUT dimension and θ is the maximum processed radiation pattern angle (Fig. 8). For a specific scanner with an allowable scan area D_p, this criterion determines the maximum and minimum AUT size ($D_{min} \approx 2\lambda$).

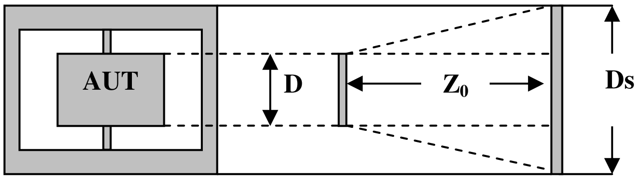

Fig. 8. Scan Size

The measured Near-Field data ***E*** (x, y, z_0) is transformed into the plane wave spectrum ***E*** (k_x, k_y) in the K-space, by a two-dimensional Fourier transform. The coordinates (k_x, k_y) in the K-space are related to the spherical coordinates (θ, φ), through the relationships $k_x = k\sin\theta\cos\varphi$, $k_y = k\sin\theta\sin\varphi$ and $k=2\pi/\lambda$. The antenna plane wave spectrum is distorted by the angular response of the probe. This effect can be deconvoluted from the AUT angular response by taking the ratio of the total plane wave spectrum to the probe spectrum. This operation is known as **probe correction**. The plane wave spectrum in the visible range, $-k< k_x, k_y<k$, is proportional to the radiation pattern F (θ, φ). Accordingly, the radiation pattern can be considered as a spatially band-limited function in the K-space on which Nyquist sampling theory applies and the sampling space can be chosen as $\Delta x<\Delta y< \lambda/2$.This sampling criterion ensures that no aliasing occurs in the visible range. For high-gain antennas are interested only in a limited angular sector around the AUT main beam.

V. MEASUREMENT OF THE SURFACE WAVE

The planar scanning technique is very expensive for experimental measurements. That is why, another technique for measuring various properties of electromagnetic surfaces have been developed [2, 3]. The presence of surface wave modes is detected in the transmission between two antennas positioned near the surface. These antennas can be simple monopole probes, or they can be specifically designed to efficiently launch surface waves. By varying the polarization of the antennas, one can distinguish between TM and TE modes [4]. The measurements on the textured surface indicate a frequency band in which there are no propagating surface waves.

The reflection phase can be measured using a pair of horn antennas directed toward the surface. The phase of the reflected wave is measured with respect to a surface with known reflection properties, such as a flat metallic surface. Within the surface wave band gap, the textured surface reflects in-phase, rather than out-of-phase.

- *TM Surface Waves*

In TM surface waves, the electric field forms that extend vertically out of the surface. TM waves cam be measured using a pair of small monopole antennas oriented normally with the respect to the surface, as is shown in fig. 9.The vertical electric field of the probe couples to the vertical electric field of the TM surface waves.

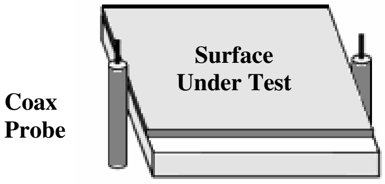

Fig. 9. TM surface wave measurement using monopole probe antennas

For improved signal, a flared parallel plate waveguide structure functions as a more effective TM surface wave antenna. This type of antenna can be made from a triangular piece of microwave circuit board material, with cooper cladding on both sides. This structure provides a smooth transition between the mode in the coaxial cable and the surface wave mode, producing a stronger transmission signal than the small monopole.

- *TE Surface Waves*

In TE surface waves, the electric field is parallel to the surface and the magnetic field forms vertical loops that arc out of the surface. They can be measured with a pair of small monopole probes oriented parallel to the sheet as shown in the Fig. 10. The horizontal electric field of the antenna couples to the horizontal electric field to the TE waves. Since this configuration lacks the symmetry of the vertical monopole where will be much greater cross-coupling to TM waves that may complicate the measurement.

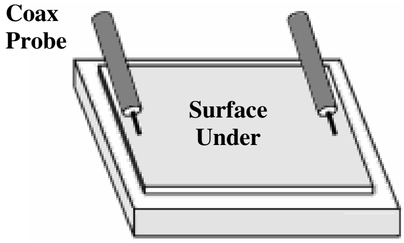

Fig. 10. TE surface wave measurement using monopole probe antennas

The typical E and H surface wave measurements using the methods shown at fig.9 and fig.10 were made by authors with vector network analyzer Anritsu 37247D. For the purposes of the measurements were used flat metal surface and FR4 dielectric slab with thickness 0,5mm and 2,5mm respectively. The frequency range is from 0.04GHz to 5GHz.

The obtained experimental results for E- and H-field are shown on fig. 11 and fig. 12, respectively. This experimental results shows that, the increasing of dielectric slab thickness, leads to increasing of mutual coupling between the ports. This effect is due to surface waves, which propagate on the material surface.

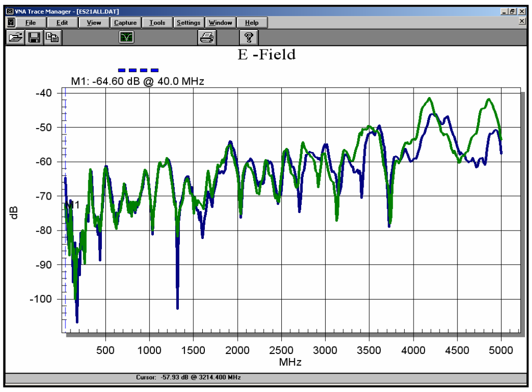

Fig. 11. E-field measurements

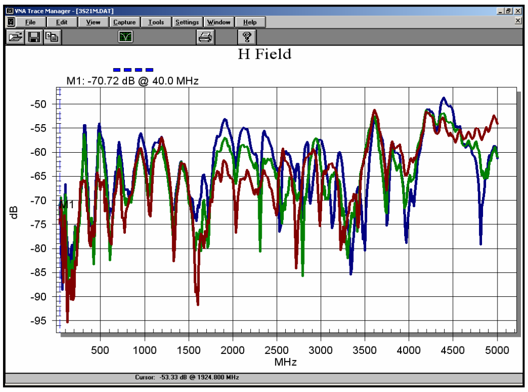

Fig. 12. H-field measurements

VI. Conclusion

Automated control system of measurements and parallel computation of the information, which is created, give a chance for continuously measurement elaboration. The measurement precision improves and the measurement time and the following treatment of the received results reduce. This type of work allows receiving enough experimental data about aposterior analysis and measurement microwave surface waves.

The accumulated measurement dates and mathematical treatments and modeling allow realizing the real action of improvement at diagram pattern of the microstrip antennas and suppressing of surface waves.

References

[1] Orbit/RF Microwave Test and Measurement Product Catalog, 1998

[2] A. Tankielun, U. Keller, W. John, H.Garbe, “Complex Deconvolution for Improvement of Standard Monopole Near-Field Measurement Results,” *Proceedings of the 16th International Zurich Symposium on electromagnetic Compatibility,* Zurich, 2005

[3] D.Baudry, A. Louis, B. Mazari, “A study and improvement of open-ended coaxial probe used for near-field measurements,” *Proceedings of the 16th International Zurich Symposium on electromagnetic Compatibility,* Zurich, 2005

[4] Yablonovitch, U. S. provisional patent application, serial number60/079953, filed on March 30, 1998