Specifications of Measuring Probes in the Near Zone of Mechatronic Systems

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Abstract: This report brings you the essential knowledge and findings regarding the measurement of microwave antenna parameters in the near zone mechatronic systems. The goal of this report is to give you an overview of the advantages and disadvantages of the near zone measurement process and comparison with measurements performed in the distant zone. Probes with low gain offer advantages from a calculation point of view, because is often unnecessary to perform compensation of the probe during calculation. This is true mostly for cylindrical and spherical scanning (spherical scanning is even less sensitive to the probe influence then cylindrical scanning).

Using probes with two orthogonally polarized signals, to ensure the scanning of two data files during one scan, will shorten the time by one half, which is necessary for data collection in comparison with traditional scanning with one output probe.

This report gives you several typical samples of probes with one or two outputs for the reception of orthogonally polarized signals. Most samples apply to probes with low gain (approximately 7 dB).

Keywords: near zone, orthogonally polarized signals, probe compensation, axial Ratio, distant zone

1. Introduction

For any measuring method, one of the most essential requirements is a reliable estimate of measurement errors. This is mostly true for antenna measurement methods in the near zone. The determination of error limits for any measuring system for an applicable combination of antenna/probe/near zone may be difficult and time consuming, whereas the mathematical complexity is the main reason for the difficulty. There is an entire range of error sources, some of which are caused by the probe. That is why it is important, during the probe specification, to consider the essential requirements that are expected from the probes.

Often experiments to skip the mathematics are performed in order to set the error limits for the general measuring technique, using the measurements for the applicable antenna.

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During this approach, the measuring results in the distant and the near zones are compared and the differences between these two methods are considered as the error criteria for measurements done in the near zone. This approach however, has several shortcomings. Firstly, the observed differences are partially due to the error influence in the distant zone. Plus it is difficult to generalize the results for another antenna or measuring system.

The most crucial measuring parameters or contributing elements from each error source cannot be determined and end measurement in the distant zone may be impractical for some types of antennas, which are suitable for measuring in the near zone.

That means that such comparisons have no value. They demonstrate reliability, help to establish credibility without detailed mathematical analysis and point out areas where more thorough and detail analysis needs to be done [1].

They are one of the parts of error analysis but in no case do they represent the entire picture. The entire and general analysis requires a combination of several approaches, analytical and experimental, in order to identify all possible error sources and their contributions to the final calculation results could be estimated.

An auxiliary antenna (probe) must be selected carefully, as suitably selected antenna may improve the precision of the measuring process dramatically, because the probe works as a space phase filter in the near zone and as space spectrum filter in the distant zone. It is possible to select probes with low gains, because the need to compensate the probe during calculation is often unnecessary. Or you may choose a probe with higher gains that offers a wider variety of advantages mainly during measurements performed on a flat surface. This report analyzes the requirements that are expected from probes used for near field measurements and includes the advantages and disadvantages of each solution. A great deal of attention is given to probes with two outputs for orthogonally polarized signals, which may reduce the measuring time by one half. A more detailed analysis of the errors influenced by the probe will be included in the report that shall focus on the influence of the environment and measuring instrument errors on the measuring results performed in the near zone [2,3].

2. Probe Compensation

It Probes with low gains are suitable from the calculation point of view, because the need to compensate the probe during the calculation is often unnecessary. This is true mostly for cylindrical and spherical scanning (spherical scanning is even less sensitive to the probe influence than cylindrical scanning). But these probes may have a worse signal/noise ratio and must be sampled in a distance that is set by the Nyguist sampling theory and demand better precision in the probe position settings.

A probe with high gain of 15 – 25 dB receives energy under a small angle in the distant zone and "will filter out" energy outside the axis. Also, the probe in the near zone will deliver an average value of higher space frequencies that correspond to the energy outside the axis. Probes with high gain are recommended if the corresponding field in the distant zone will be calculated for small angles (five

degrees or less). Although these probes modify the emitting diagram, you may perform compensation of the emitting probe diagram.
Probes with high gains have four major advantages:

a) They increase the signal/noise ratio, because the non-adaptability is decreased (contrary to measurement in distant zone, because the existing amount of energy must cover a larger area).
b) They filter the field in advance and by doing so (according to the Nyguist sampling theory) they increase the distance of the scanning that would otherwise be half of the wavelength (it is sufficient to sample from a distance of five wavelengths or more).
This speeds up the scanning significantly.
c) They reduce the reflection influence from the ground and surrounding objects.
d) They lower the demands on the precision setup of *x* and *y* coordinates, because elements with high space frequencies change phase rapidly. Requests on the *z* axis remain unchanged.

There is a limitation of all measurements performed by scanning in the near zone, and it is determined by the level of suppression of still waves influenced by multi reflections (multi-passages) relevant to the applicable configuration of the measured antenna and probe. In cases when the measured antenna has lower electric dimensions, it is practical to lower the multi reflections by increasing the distance between the aperture of the funnel probe and the structure of the measured antenna.

In this case, often the separating distance of 10 to 20 wavelengths will suppress the signal for the second passage to level -40 dB. But during measurement of electrically large antennas, it has been discovered that a separation of 10 wavelengths may correspond to suppression of the second passage of only 25 dB for an open rectangular funnel [3].

Even though there are many different methods for solving this problem, the two most common represent the use of the average value for multi-scanning and minimize the dimension of the probe aperture. Multi-scanning is a practical method used just for this purpose. During this method the measurement is done on several surfaces (based on the method used on flat surfaces or on cylindrical or spherical surfaces) that are 1/8 of a wavelength apart. The average value is calculated from final radiation characteristics in the distant zone. This approach is very successful and it is usually integrated as an option in programmes that deal with processing the measuring results. The minimization of the probe aperture lowers the dispersion-reflective surface of the aperture structure used.

3. Probe with two outputs

A Using probes with two orthogonally polarized signals, to ensure the scanning of two data files during one scan, will lower the time to one half, which is necessary for data collection in comparison with traditional scanning with one output probe. This also enables us to use simpler construction because the mechanism for probe rotation (around the probe axis) is unnecessary. In combination with the automatic measuring system, probes with two outputs enable us to utilize the apparatus to its maximum capacity.

For the applicable probe it is necessary to measure the gain on the axis, axis ratio, tilt angle and direction of rotation. Samples of gain measurements and polarization for probes with one and two outputs are shown in Charts 1 and 2.

Chart 1. Axis measuring results of a typical probe with one output

Frequency [GHz]	Gain [dB]	Axial ratio [dB]	Tilt angle [°]	Direction of polarization
12.0	6.21±0.11	55.6±2	89.5±0.2	Left
14.0	6.50±0.11	57.6±2	89.1±0.2	Left
16.0	7.02±0.11	62.5±2	89.2±0.2	Left

Chart 2. Axis measuring results of a typical probe with two outputs

Frequency [GHz]	Port	Gain [dB]	Axial ratio [dB]	Tilt angle [°]	Direction of polarization	Reflection coefficient	
						Amplitude	Phase [°]
12.0	X	16.42±0.11	24.8±2	-0.5±0.2	Left	0.492	-47.1
14.0	X	16.41±0.11	24.1±2	0.0±0.2	Left	0.464	-69.5
16.0	X	16.65±0.11	23.5±2	-0.5±0.2	Left	0.513	-85.9
12.0	Y	16.65±0.11	38.5±2	90.7±0.2	Right	0.484	-44.7
14.0	Y	16.50±0.11	34.7±2	90.7±0.2	Right	0.460	-67.3
16.0	Y	16.63±0.11	32.6±2	90.4±0.2	Right	0.513	-84.0

The required and necessary properties of a probe with two orthogonally polarized outputs are:

- high polarization purity
-good insulation between both ports
-mutual and shared reference system of coordinates
-aperture with a small dispersion value
-possibility to connect the probe repeatedly to the high-frequency track
-suitable installation of connection

Probes with two outputs use square or circular waveguides with dielectrical filling. This approach however, worsens the adaptability of the probe aperture and requires careful inspection of the dielectrical material in order to discover the clear and symmetrical emitting characteristics of the probe.

Another option is to use a circular waveguide with a diameter above the critical value but at the same time it cannot be too big (that means higher modes could not spread). That will minimize the aperture dimension and relevant wave reflection but it leads to a somewhat narrow frequency band.

As a sample, we may use a probe that is designed for frequencies from 5.25 to 5.35 GHz with a diameter of circular waveguide 41.9 mm, when the low working frequency is 1.25 times the critical frequency for mode TE_{11} and the upper working frequency is 0.78 times the critical frequency for mode TE_{21} and 0.98 times the critical frequency for mode $TM_{01.}$ The nominal dimension of the wall thickness of the waveguide of 3.175 mm is narrowed to only 1.016 mm in the aperture in order to further minimize the reflection surface. The probe assembly has been calibrated by the National Institute of Standards and Technology (NIST) in the USA. The specifications of this probe are shown in Chart 3 and the results of this calibration are shown in Charts 4 and 5. It is clear that adaptability problems begin at the upper edge of the frequency band.

Chart 3. Probe specifications for frequency bands from 5.25 to 5.35 GHz

Characteristics	Specifications
Construction type	Circular waveguide
Polarization	Double, linear
Axial ratio	>35 dB
Insulation between ports	>40 dB
Gain	7 Up to 9 dBi, nominal
Still wave ratio	2.0 times maximum
Type of connectors	APC-7

Chart 4. NIST calibration results for port 1

Frequency [dB]	Power gain [dB]	Axial ratio [dB]	Direction of polarization	Tilt angle [°]	Reflection coefficient Amplitude	Reflection coefficient Phase [°]
5.250	8.00	73	Left	-1.4	0.043	-144.0
5.275	8.01	60	Left	-1.4	0.082	-97.9
5.300	7.98	67	Left	-1.4	0.148	-125.0
5.325	8.09	56	Left	-1.4	0.192	-158.5
5.350	8.11	76	Left	-1.2	0.203	165.8
Error estimate	±0.11	±5		±0.4		

Chart. 5. NIST calibration results for port 2

Frequency [dB]	Power gain[dB]	Axial ratio[dB]	Direction of polarization	Tilt angle [°]	Reflection coefficient Amplitude	Reflection coefficient Phase [°]
5.250	7.60	58	Left	88.7	0.016	-114.8
5.275	7.65	67	Left	88.8	0.075	-107.7
5.300	7.63	81	Right	88.8	0.124	-118.8
5.325	7.72	64	Left	88.8	0.164	-130.8
5.350	7.79	69	Right	88.9	0.195	143.9
Error estimate	±0.11	±5		±0.4		

This report gives you the essential information necessary for probe selection used for measurements in the near zone. Here you may find basic requirements for probes with higher gains, which may only be used for calculations of a smaller angular range (e.g. 5°). However, for these types of probes you have to use probe corrections.

Using a probe with two outputs of orthogonally polarized signals for scanning two data files during one scan reduces the time needed for data collection by one half, in comparison with traditional scanning done with a probe with one output only. This also enables us to use simpler construction, because a mechanism for probe rotation (around the probe axis by 90°) is not necessary. In combination with an automatic measuring system, probes with two outputs enable us to utilize the apparatus to its maximum capacity.

4. Conculsions

The insulation between ports should be greater than 20 dB. Insufficient insulation between ports X and Y causes the measuring process to depend very much on reflection endings for an orthogonal port (if you are using a two-channel receiver with input impedance of this receiver). As seen from the published specifications, the insulation is usually greater than 40 dB. However, it is necessary to ensure that during the use of the probe, the endings of the outputs do not differ significantly from the ending during the measurement.

References

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