Complete Analysis of Spherical Higher Order Mode Excitation in Antenna Measurement Probe

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***Abstract*— Classical probe corrected Spherical Near Field (SNF) measurement assumes a |μ| = 1 probe [1]-[3]. This requirements is needed to fully compensate the effect of the probe during the NF/FF transformation [3]. If the probe has an higher order mode content, a residual error will affect the measured pattern (probe modal truncation).**

This requirement leads to challenging probe designs especially if the required bandwidth is wide and/or there is a limitation on the acceptable dimension. As a consequence, in many practical cases, higher order spherical modes could be radiated.

In this paper, the source of higher order spherical modes of the MVI SP1100 probe is investigated using MV-INSIGHT software [6] which reconstructs equivalent currents starting from the measured NF. The equivalent currents associated to higher order modes have been computed on a conformal geometry encompassing the probe. In this way, the origin of such higher order modes has been deduced.

***Keywords*— antenna measurements, first order probe, spherical wave expansion, equivalent currents.**

I. INTRODUCTION

In this paper the spherical modal content of the SP1100 first order probe, designed by MVI and shown Fig. 1, is analyzed in detail in order to understand the source of higher order modes.

The analysis have been carried out using the commercially available MV-INSIGHT [6] software that, starting from the measured NF, allows to compute equivalent electric and magnetic currents on an surface fully enclosing the AUT/DUT.

In particular, spherical modes with indices |μ| ≠ 1, have been isolated from those having indices |μ| = 1 and the corresponding equivalent currents have been computed on a surface conformal to the probe shape. The main goal of the study is to understand if the higher order spherical modes are directly radiated by the aperture or generated by the interaction between the probe itself and other probe parts such as the absorber collar or supporting structures.

The MVI SP1100 is a wideband and electrically small L-Band probe working in the frequency range 1.1-2.0 GHz.

The SP1100 consists of a quad-ridge wide band dual polarized orthomode junction (OMJ) [5] feeding a conical aperture. The OMJ is based on a quad-ridge circular waveguide with external feeding circuits. The OMJ feeds directly into a circular waveguide, providing a stable wide band performance and the necessary symmetry for mono-mode excitation is enforced by balanced feeding from external feeding circuits.

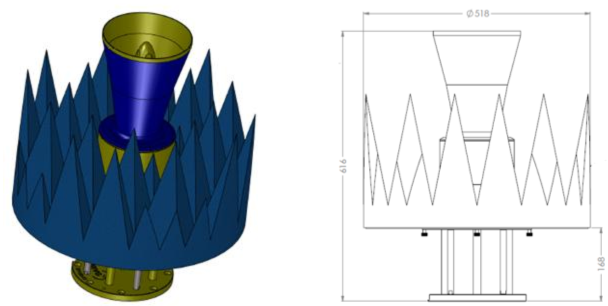

Fig. 1. CAD model of the MVI SP1100 probe.

The probe performance have optimized also trying to limit the probe length. The height of the probe excluding the stand-off is in fact less than 1.5λ at 1.25 GHz. Despite such compactness, the SP1100 probe can be considered a first order probe up to 1.6 GHz (modes indices |μ| ≠ 1 are lower than -35dB).

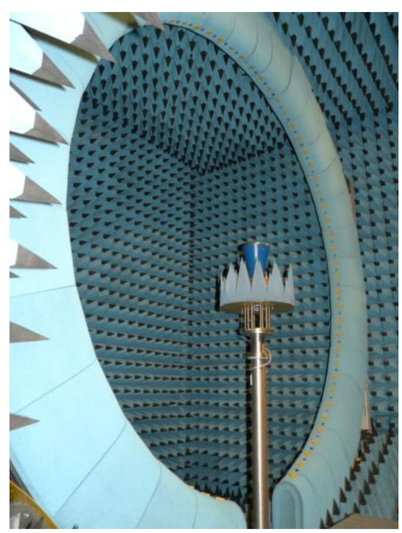

Fig. 2. MVI SP1100 probe during SNF measurent in MVG SG64 spherical multi-probe system.

The MVI SP1100 has been characterized in terms of radiation pattern and spherical mode spectrum performing SNF measurement. The probe during measurement in the MVG SG64 spherical multi-probe system sited in Paris is shown in Fig. 2. As can be seen the circular absorber collar also shown in Fig. 1 has been included in the measurement as part the AUT.

The directivity patterns obtained transforming the acquired SNF samples to FF are reported in Fig. 3 for the main cuts.

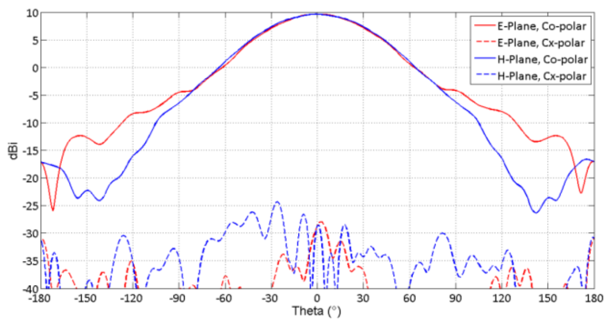

Fig. 3. Measured directivity pattern of the MVI SP1100 probe @ 1250MHz. E-plane pattern cut (red traces); H-plane pattern cut (blue traces).

Similarly, the spherical mode spectrum represented by the Pn and Pm curves is illustrated in Fig. 4. As can be seen from the Pm-curve spherical modes $|\mu| \neq 1$ are well below the -35dB threshold, as expected.

Despite the low level of the higher order modes it is interesting to analyze them in order to understand if they are directly radiated by the aperture or generated by the interaction between the probe itself and other probe parts such as the absorber collar. The outcomes of such analysis could then be taken into account for further optimization of the probe performance in future design.

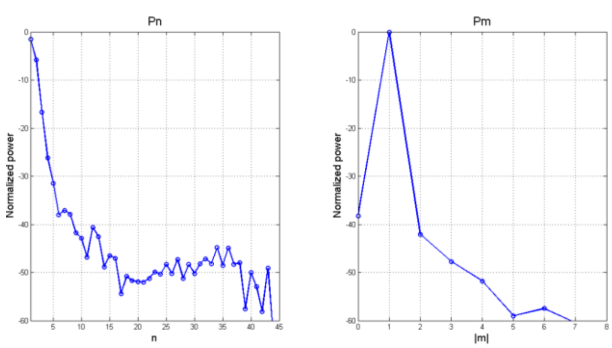

Fig. 4. Measured spherical mode spectrum @ 1250MHz of the MVI SP1100 probe. Pn-modes (left); Pm-modes (right).

II. Source of Higher Order Spherical Mode

In order to perform the spherical mode analysis the MV-INSIGHT software [6] has been used. Such software is based on the equivalent current approach (EQC) / Inverse Source Technique [7]-[11]. Based on the acquired NF data, the equivalent electric and magnetic currents are determined on an arbitrary shaped reconstruction surface conformal to the test object.

As an example, the electrical equivalent currents of the measured SP1100 probe are illustrated in Fig. 5 (right). As can be seen an equivalent geometry conformal the probe shape, including the absorber collar, has been used. As expected, most of the electrical current power is concentrated on the probe aperture while a much lower, but not negligible, power is spread over the absorber collar.

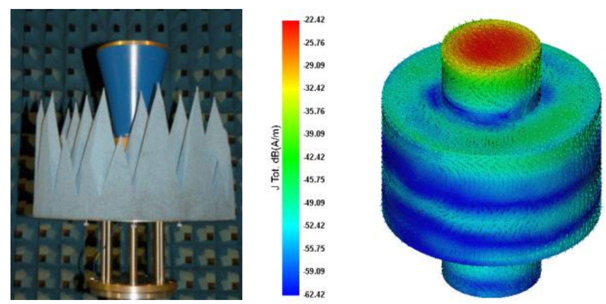

Fig. 5. Equivalent electric currents @ 1250MHz evaluated on an equivalent geometry encopassing the MVI SP1100 probe.

A similar approach has been used to perform the spherical mode analysis of the SP1100. In particular, starting from the spectrum shown in Fig. 4, different subsets of spherical modes with indices $|\mu| \neq 1$, have been isolated from the full spectrum (band-pass filtering) and the corresponding SNF have been recomputed at the same radius of the SNF measured by the SG64. The computed SNF has then been used as input field to the MV-INSIGHT software. The equivalent currents associated to a particular subset of spherical modes have thus been computed on the same equivalent surface encompassing the SP1100.

With such a procedure, the $|\mu| = 0$ modes of the measured SP1100 have been first analyzed. The computed electric equivalent currents associated to the $|\mu| = 0$ modes are shown in Fig. 6. As can been seen these currents are more than 55dB below the peak (peak is at -22.4dB as shown in Fig. 5-right), nevertheless it is possible to locate their main contribute on the probe main radiating part. In particular, observing the probe aperture (see top-view shown in the right part of Fig. 6), it is possible to recognize the shape of the undesired TM_{01} circular waveguide mode [12].

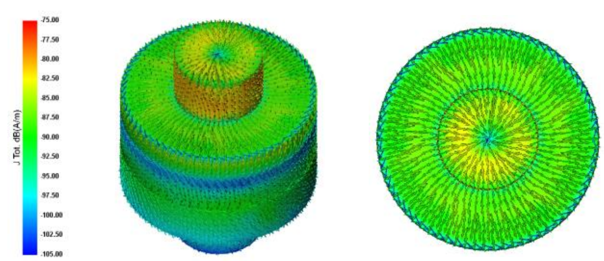

Fig. 6. Equivalent Currents @ 1250MHz associated to $\mu = 0$ spherical modes only. 3D-view (left); top-view (righ).

The same procedure has been also applied to spherical modes having indices $|\mu| > 1$. The computed electric equivalent currents associated to the $|\mu| > 1$ modes of the measured SP1100 are shown in Fig. 7. Even in this case it is possible to identify the main radiation contribute on the main radiating part of the probe. This time, observing the probe aperture (see top-view shown in the right part of Fig. 7), it is possible to recognize the shape of the undesired TE_{21} circular waveguide mode [12]. It should be also noted that contributions of minor intensity are also distributed as hot spots on the absorber collar.

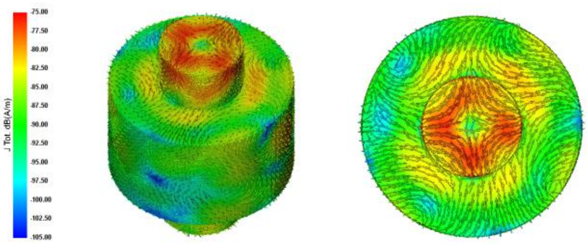

Fig. 7. Equivalent Currents @ 1250MHz associated to $|\mu| > 1$ spherical modes only. 3D-view (left); top-view (right).

Both results shown in Fig. 6 and Fig. 7 illustrate that spherical modes with indices $|\mu| \neq 1$ are principally radiated by the probe aperture. The cause of such an effect is most probably due excitation error in the BFN, that generates TM_{01} and TE_{21} circular waveguide modes that in turns generate the spherical higher order modes. It is observed that the interaction between the probe aperture and the absorber collar is also a source of higher order spherical modes.

III. Conclusions

In this paper the spherical modal content of the SP1100 first order (or $|\mu| = 1$) probe has been analyzed in detail in order to understand the source of higher order modes. The investigation has been carried out using the commercially available MV-INSIGHT [6] software that, starting from the measured NF, allows to compute the equivalent electric and magnetic currents on an conformal surface fully enclosing the AUT/DUT. In fact, starting from the spherical NF measurement of the SP1100 at 1250 MHz, the spherical modes with indices $|\mu| \neq 1$ have been isolated from those having indices $|\mu| = 1$ and the corresponding equivalent currents have been computed on a surface conformal to the probe shape. In particular, two cases have been studied:$|\mu| = 0$ spherical modes and $\mu| > 1$ spherical modes.

It has been observed that $|\mu| = 0$ and $|\mu| > 1$ spherical modes are mainly caused respectively by the undesired TM_{01} and TE_{21} circular waveguide modes. Such circular waveguide guided modes are most probably generated by excitation error in the BFN. It has been also observed that the interaction between the probe aperture and the absorber collar is also a source of higher order spherical modes.

Such outcomes of the performed analysis represent a important input for further optimization of the probe performance in future design.

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