Bridging the Gap: Bringing Measurements and Computational Results Together

Vince Rodriguez[1]

[1] MI Technologies, Suwanee, GA, USA, vrodriguez@mitechnologies.com

***Abstract*—Is there a gap between Computational and Measurement Electromagnetics? The author believes that there is. That those involved in engineering electromagnetics using numerical methods and those performing measurements of electromagnetic devices have drifted apart in the recent years. The improvement of numerical tools available commercially seems to have some part in the widening of this gap. Additionally the improvement of measurement tools and instrumentation seem to have given the community of EM metrologist, the belief of better measurements and results. As the author studied this apparent gap he believes that the ease of use of these tools has reduced the amount of training necessary. Also the author believes that the confidence on the tools has eliminated the use of *a priori* knowledge of the problem's solution as well as a dose of skepticism. While computational electromagneticists seem to have a blind faith on their tools, the metrology group seem to believe that the computational results are models with little place in the real world where they perform the measurements. As a way to try to bridge this gap the author looks at a series of case studies where numerical results benefit form measurements and measurements benefit from numerical results. In conclusion, the author believes that the most important ingredient in closing the apparent gap between measurements and computed results is to question the results of the simulation or measurement and to understand if they are physical results or errors of some kind. The lack of that skepticism may be tied to the easy-to-use tools available that minimize the need for training on the underlining theory of the phenomena being measured or computed.**

***Index Terms*— Computational EM, Measurements.**

I. Introduction

Is there a gap? That is the question. Is it a real gap or friendly "trash talk" between colleagues? Who is the author to open this debate? The author is an engineer that had training in computational electromagnetics, completing higher degrees in this area of engineering electromagnetics, while having long a career in companies that are dedicated to measurement system for electromagnetic waves. Over the years the comments have been heard. Paraphrasing some of the comments heard, the measurement side takes the position that there are models and there is the real world. The computational side takes the side that their approach is derived directly from Maxwell's Equations, hence their results are the correct ones. These are of course extreme points of view, but comments like can be heard at many symposia from different people. The author believes that there is a gap, and points the reason to the improvements on measurement and computational tools. In a way the engineers have become victims of their own success. On the measurement side, lower uncertainties are achieved, higher frequencies can be measured, better instrumentation is available and software control has made it easier to use. On the computational side, there are faster computers, higher amounts of memory, more accurate methods and ease of use. The ease of use is one of the main problems. Ease of use leads to less training required. Some of the basic principles are forgotten. On the metrology side the uncertainty principle is forgotten. The moment a measurement is made we are affecting the quantity that is being measured. On the computational side the assumptions used in deriving the method are not known or are ignored. In the following sections a series of cases are reviewed that show how the gap can be reduced and how each of these two approaches can benefit from each other. They also show how the ease of use and lack of understanding of the basics can lead to the creation of the gap.

II. Case 1. Dipole measurement and the blame game

This case was previously presented in [1]. While [1] does not explain the reasons for the study the amount of modeling performed on the dipole was caused by the gap. The dipoles modeled are sleeve dipoles used for over-the-air (OTA) cell phone tests, Figure 1 shows one of these dipoles. The same procedure is used for wi-fi devices in many cases so a dipole operating in the 5.5 GHz range was required. The variation on the azimuth pattern cannot have a variation larger than 0.2dB. The dipole must be isolated from the feed cable to avoid the effects of the cable on the range calibration measurements. Computational tools were used to model the dipole to arrive at a design. The results shown in figure 2 were acceptable and the prototypes were manufactured and sent to testing. The problem arose when the azimuth variation of the pattern was measured. The results (shown in figure 3) indicated that the dipole had an azimuth variation larger than the 0.2 dB required.

Fig. 1. A 5.5GHz Sleeve dipole like the ones modeled in case one. The Styrofoam cover protects the delicate elements of the dipole.

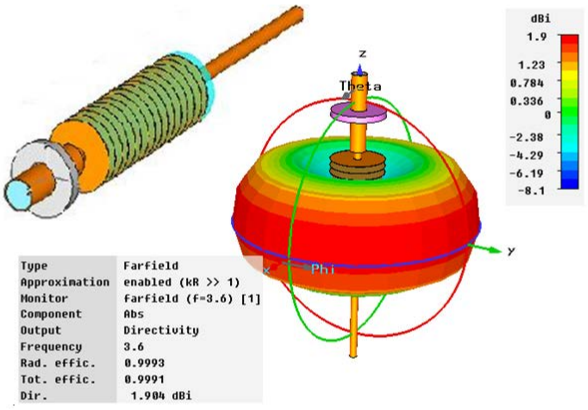

Fig. 2. Pattern results for 3.6 GHz version of the sleeve dipole . The dipole model is shown on the left. The round features along the feed cable are ¼ wavelength chokes.

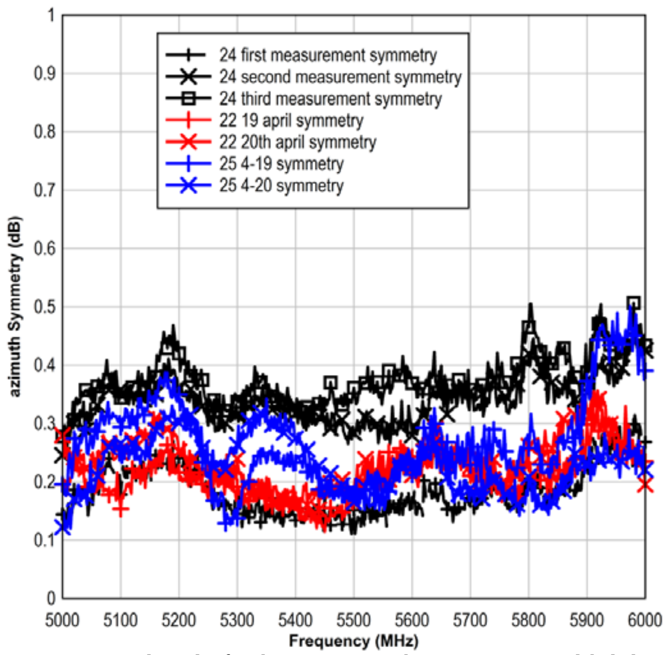

Fig. 3. Measured results for the prototypes. Three separate units labeled 24, 25 and 22, measured different times. The azimuth symmetry or variation on the pattern around the dipole axis is larger than 0.2 dB.

The discussion arose after the measurements about the reason why the simulations predicted that the design was going to perform while the measurements showed all dipoles failing to meet the requirement. The computational group stated that successful designs of similar dipoles have been done using the same tools and that the failure must be on the measurement system. Had the system been check at 5.5 GHz? The measurement group blamed the construction of the dipoles. Misalignment of the dipole element, and gaps of the choke assembly were blamed for the poor results. There was a gap, a clear disagreement on what was the cause for the poor measured results. As presented in [1] a series of simulations were performed to see what the effects of the alleged manufacturing defects were on the performance. In figure 4 the case with several defects at the same time is shown. This showed that even with several defects the azimuth variation remained under 0.2 dB.

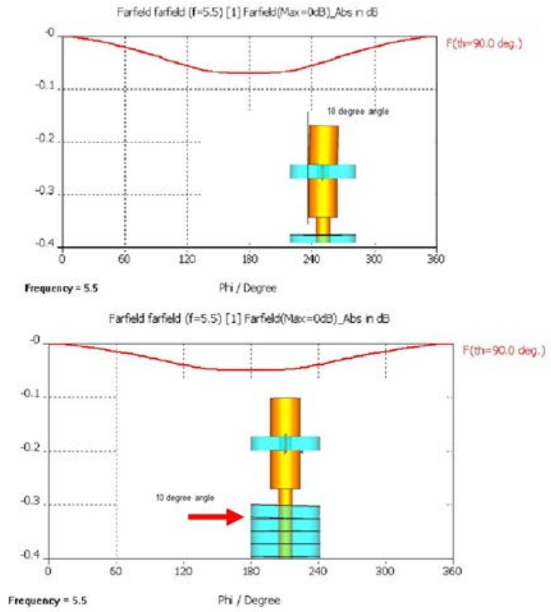

Fig. 4. Variation of the radiation in azimuth for one case with the top element bent by 10 degrees and a second case with the first choke section bent by 10 degrees.

The measurement group was asked to check their system. The author proposed a test where the dipoles were removed and an attenuator was included to model the path loss. The system was then set to take data on a direct connection at the same rate as it is taken during the azimuth pattern test. The results show that at these frequencies the difference between the maximum and minimum values was in some cases close to 0.08 dB (see figure 5). A small value, but not small enough when the goal is 0.2 dB. In addition this test did not include the mechanical vibrations when the antenna is being rotated. Thus cooperation between both sides of the gap solved the issue. The computational group showed that while manufacturing issues could have an effect, this effect was less than 0.1 dB.

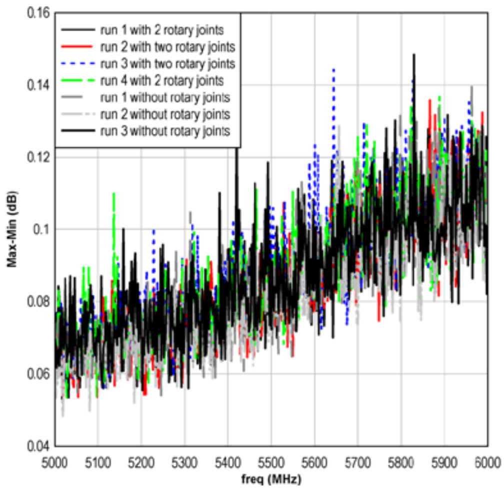

Fig. 5. Verification of the measurement system in the frequency band.

The measurement group learned that the high losses at the high frequencies caused the instrumentation to be in a region where the uncertainties got close to the values being measured. Amplification was added to the system to increase the signal level. Part of the issue in this case was human nature. Everybody wants to be right. However, scientists and engineers should be willing to put their assumptions to the test. That is something that engineers should be train to do, but the success of software packages and better equipment (and the marketing by their manufacturers) seem to have pushed to the side the verification of the results.

III. CASE 2. USE YOUR KNOWLEDGE

In this case a pattern measurement is analyzed. There are going to be differences between the computed and the measurement results. These differences can lead to the gap. This is an issue that the author, and we are sure the readers, have encountered over and over. Which one is the true result? We all must use our knowledge to explain the difference and accept the limitations of our tools. The true value is somewhere in the middle and that is why some uncertainty value should always be given. Let us look at the measured and computed VSWR of the antenna. Figure 6 shows the computed results for the VSWR of a dual polarized quad ridge horn. The horn data was originally presented in [2]. Figure 6 also shows the VSWR for the two orthogonal ports that feed the antenna. While there is good agreement from 1 to 4 GHz, at higher frequencies the difference is close to one unit of VSWR. At 13.5 GHz the difference between the computed and the measurement for port B is as high as 6.25 dB. Is there a problem with me measurements or with the model? Knowledge bridges the gap. There are model assumptions. A single port was modeled to reduce the mesh required. Also at higher frequencies, a lower number of cells per wavelength were used to allow for the geometry to solve in the available computers. Also the simulated port was at the position of port A, The orthogonal port B was a few mm off and the effects of the position are seen at higher frequencies.

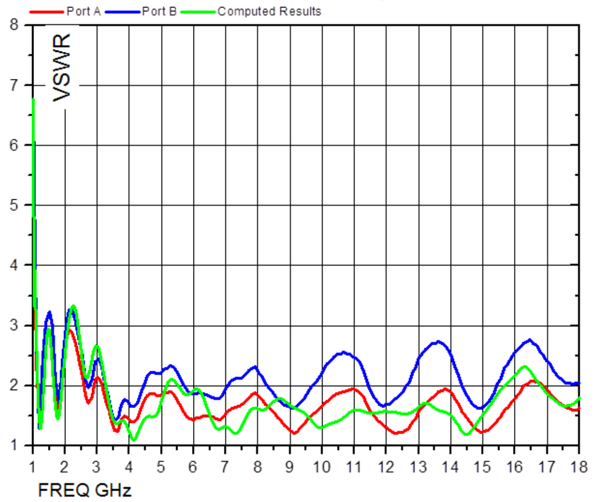

Fig. 6. The measured and computed VSWR for the quad ridge horn introduced in [2] showing the higher differences at higher frequencies.

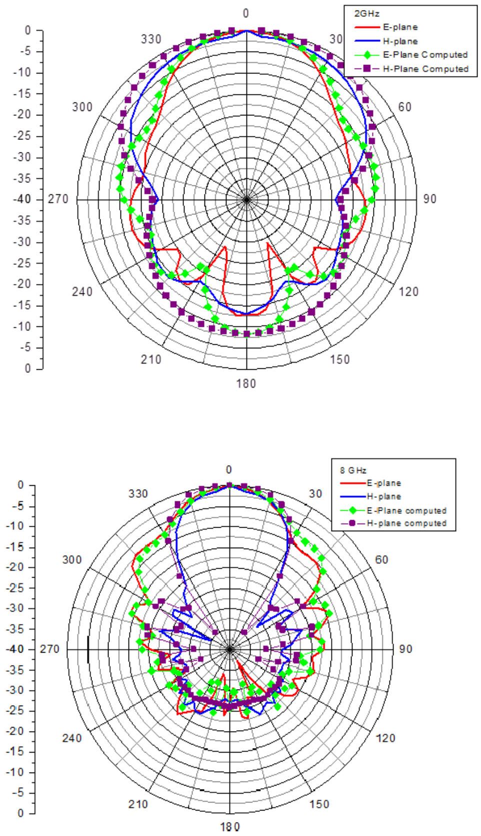

Fig. 7. The measured and computed radiation patterns at 2GHz (top) and 8GHz (bottom) for the antenna introduced in [2].

So the model had some limitations and hence the difference that we see on the VSWR. But then we have the measured pattern. Figure 7 shows the computed and measured patterns on the two principal planes for one of the polarizations at 2 GHz and 8 GHz. At 2 GHz there is some clearly disagreement between the computed and measured. At 9 GHz the agreement seems to be better. This is opposite what was seen for the VSWR where the biggest difference was in the upper half of the frequency range. Is the model failing at the lower end of the band? The antenna is supported by a dielectric positioner fabricated from a 5cm by 5cm fiberglass tube. It is expected that its effect be larger at higher frequencies as the positioner size is in the order of a wavelength. And our knowledge tells us that the model should be more accurate at lower frequencies as we have more accurate finite differences. How about the measurement facility? The anechoic chamber is 3.6 by 3.6 by 7.2 m It is lined with 60 cm absorber. An analysis of the quiet zone (QZ) shows that at 2 GHz the QZ level achieved is about 22 dB. As we go to higher frequencies we get better absorption, and better QZ levels, hence better measured data. No gap was created, no finger pointing. Understanding of the tools and possible limitations has explained the differences in results. But this requires a set of theoretical knowledge that the user does not always have, because given the ease of use of both computational software and measurement systems the operators do not always have the required knowledge needed to bridge the gap by explaining the differences.

IV. CASE 3. DO THE RESULTS MAKE SENSE?

The third case illustrates how the blind faith on the tools used leads to the gap. In this case a horn designed to do EMC immunity measurements. The horn was recommended based on its performance to do immunity testing on vehicles at 2 m distance, per the ISO 11451-2 standard [3]. The measured data presented in figure 8 shows that on average over 2 kW of power is required to generate 100 V/m. This does not seem right, at 2 GHz the gain of the antenna is 8 dBi, and the half power beamwidth is less than 60 degrees for both planes. A very simple approximation using (1) tells us that the required power should be much lower.

$$|E|(V/m) = \frac{\sqrt{30 \cdot P_{in} \cdot g_a}}{d(m)} \qquad (1)$$

Where d is the test distance, g_a is the linear gain of the antenna and P_{in} is the input power. Equation (1) shows that the power required for 100V/m at 2m distance should be about 215w.

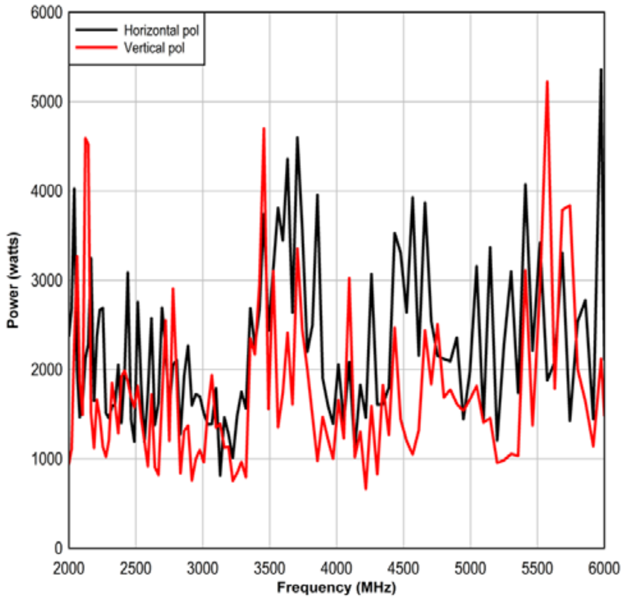

Fig. 8. Measured power required at the antenna input to generate 100V/m at 2m distance and 1m over a metal ground plane as required by ISO 11451-2 for automotive testing.

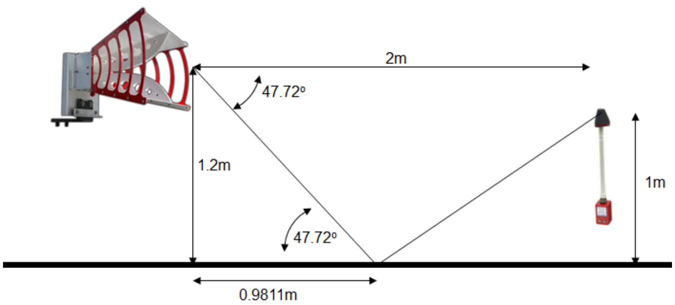

Fig. 9. The geometry of the test per the ISO 11451-2 standard. The reflected ray is about 9dB lower than the direct ray to the broadband field probe.

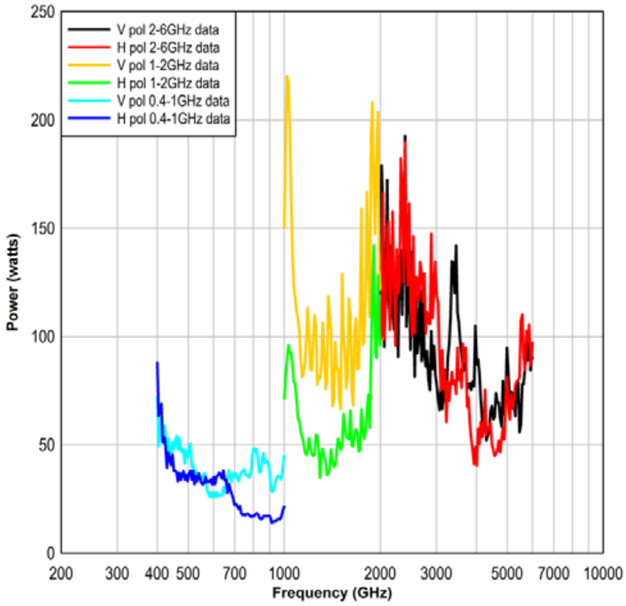

Fig. 10. Data measured per the ISO 11452-2 at different bands showing a large discontinuity at 1GHz.. Amplifiers and couplers are switched at 1, and 2GHz.

However, the measured data was showing that more than 1kW was required, more than 2.5kW for the horizontal polarization.

While it is true that (1) is an approximation that does not take into account the ground effects, the difference between the expected value and the measurements is over 10 dB. The ground may have an effect, but given the pattern on the antenna and the geometry of the test, shown in figure 9 the field illuminating the ground in the specular point is 10dB lower than the direct illumination. Hence the a priori knowledge of the problem is telling us that there is something wrong with the measurement system. However, the technicians strongly insisted that the measurement system was fine. The ease of use has taken away the need for training. The measurement group had taken data at lower frequencies which had agreed well with computed and expected values. In addition to the data per ISO 11451-2, data per the ISO-11452-2 [4] standard is also measured. Plotting the data measured per the ISO 11452-2 above and below 1 GHz clearly shows that there is a problem with the data measured. The plot is shown in figure 10. Clearly there is a large discontinuity at 1 GHz. The persons performing the measurements failed to see this because of a high confidence on the tools that they use. The high levels of automation on the tools available have given the users the idea that sanity checks are not required. This is a problem also seen on the numerical side. Many users set up problems and run simulations without really understanding what the tool is doing.

In this particular case, as the frequency bands change, some of the components on the measurement had to be switched. However, the coupling factors used by the software to calculate the actual power out of the amplifier from the power measured by the power meters were not change. The software was functioning and data was being saved to the output file, but this data was for all purposes garbage. The ease of use of

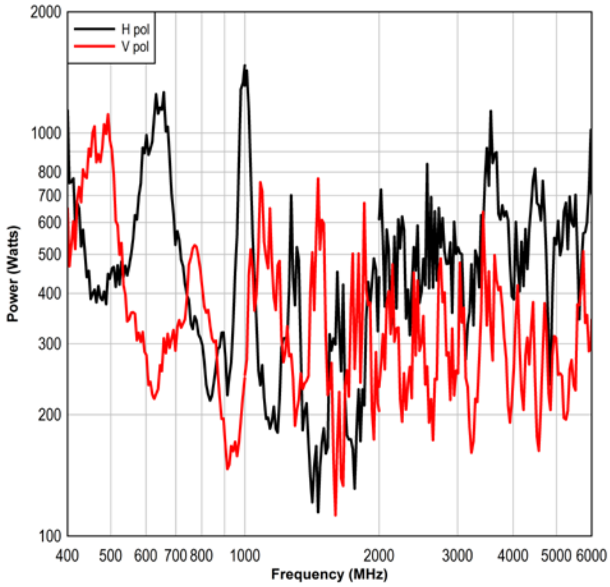

Fig.11. Measure data for the ISO 11451-2 showing a small transition at 1 GHz and 2 GHz. The data was taken after the proper coupling factor files were used for the power measurement.

the tool may have cause the technician to be careless. Similarly easy to use computational software can lead to overconfidence.

Figure 11 shows the power data for generating 100 V/m at 2 m distance. While there is still a difference with the computed data from (1) it must be remembered that the equation does not take into account floor reflections, or chamber effects. Additionally the probe is not on the boresight of the antenna, thus, the antenna gain is slightly lower.

V. CONCLUSION

The thesis of this paper was that there is a gap between computational EM and EM measurements. A secondary thesis is that easier to use software packages and instrumentation have reduced the level of knowledge required to use these tools. In all the cases presented it was clear that closing the apparent gap required questioning the results. It appears that the step of questioning the results is not present in many cases today. This step of questioning the results is a simple step. It means to understand the EM, to explain why they results are as they appear. It means to understand the approximations and assumptions. The gap in general seems to appear from a blind faith on the tools used and a lack of understanding of the techniques and approaches used by the other group. It is not fully spread, across the profession, but it is present on some cases.

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REFERENCES

[1] V. Rodriguez “Numerical Analysis of Sensitivity of Precision Reference Dipole Performance To Manufacturing Tolerances and Workmanship” 30th Annual Antenna Measurement Techniques Association Symposium AMTA 2008,Boston MA,Nov. 16-21

[2] V. Rodriguez, “Open-Boundary Quad-Ridged Guide Horn Antenna for Use as a Source in Antenna Pattern Measurement anechoic Chambers” 27th Antenna Measurement techniques Association Symposium AMTA 2005, Newport R.I. oct 30- Nov 4th 2005.

[3] ISO 11451-2 “Road vehicles -- Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 2: Off-vehicle radiation sources” *International Standards Organization* (ISO) Standard document.

[4] ISO 11452-2 “Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 2: Absorber-lined shielded enclosure” *International Standards Organization* (ISO) Standard document.