Comparison of return loss calculations with measurements of narrow-band microstrip patch antennas

Hossam Abdallah, Wasyl Wasylkiwskyj
Department of Electrical and Computer Engineering, The George Washington University
Washington DC 20037, USA

Kunal Parikh, Amir Zaghloul
Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University
VA 22043, USA

Abstract: The return loss of rectangular, single- layer, coax- fed patch antennas designed to resonate at 1904 MHz was computed using WIPL-D and HFSS and the results compared with experiment. It was found that neither WIPL-D nor HFSS estimates the bandwidth and the resonant frequency with sufficient accuracy. However, the resonant frequency predicted by WIPL-D was found to be closer to the experimental value than predicted by HFSS.

1. INTRODUCTION

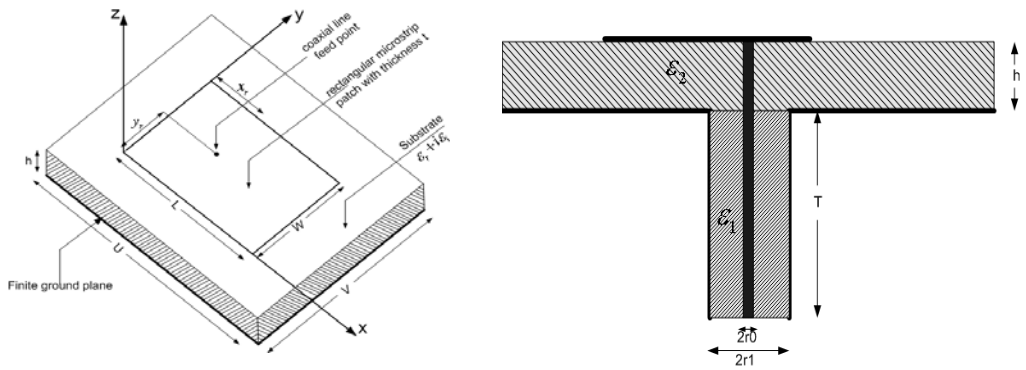
With growing use of microstrip antennas in a variety of applications, there is a great need for modeling and analysis software packages that can accurately and efficiently predict the performance of these antennas. The cost, ease of use, and the time spent in both the design and calculations are additional and important key factors in selecting a software package. A number of microstrip antennas modeling software packages are compared in [1] where it is shown that custom-written codes are more accurate than standard commercial packages. In this paper designs of single-layer coax fed rectangular microstrip patch antennas are examined using WIPL-D and HFSS (High-Frequency Structure Simulator) software packages and the results compared with experiment.

WIPL-D is a frequency domain moment method program that models metallic and/or dielectric/magnetic structures (antennas, scatterers, passive microwave circuits, etc.) [2]. The geometry of the structure is defined in an interactive way using a combination of wires, plates and material objects. HFSS is a frequency domain finite element code. The version used in this paper is Agilent Version 5.6.
Instead of using the performance measures introduced in [1] here comparisons of computed and experimental results employ the return loss as a function of frequency.

The initial patch dimensions and substrate thickness were chosen on the basis of a standard simplified transmission line model [3], [4] and subsequently adjusted in accordance with repeated applications of WIPL-D. Once the dimensions and feed point position that yield a match at the desired resonant frequency (1904 MHz) were determined the return loss was computed as a function of frequency. Both a single patch and a 3-element linear patch array were modeled. The calculations were then repeated with HFSS. Several patch antennas were fabricated with dimensions held to within 10 μ of the values used in the calculations. Special care was exercised to duplicate the physical parameters of the coaxial feed used in the computer models. Measurements of return loss were carried out using a carefully calibrated HP 8722D network analyzer.

2. PATCH GEOMETRY AND COAXIAL FEED

Fig.1(a) shows the geometry of a single-layer patch antenna, where L denotes the length and W the width. The patch is fed by a coaxial line (Fig.2) with the feed point located at x_r and $y_r = W/2$. The dimensions of the rectangle defining the extent of the ground plane are denoted u and v. Fig.1(b) shows the crosssection of the rectangular patch and substrate in the E-plane. The length of the coaxial line is T and the radii of the inner and outer conductors are r_0 and r_1, respectively. The relative dielectric constant of the coaxial line is ε_1 and only the inner conductor is extended into the substrate. The coaxial line characteristic impedance was kept at 50 Ohms with r_0 and r_1 as well as the dielectric constant chosen to corresponding to a standard SMA connector.



(a) (b)

Fig.1 Rectangular microstrip patch, **(a)**, E-plane cut, **(b)**

3. COMPARISON OF RETURN LOSS COMPUTED USING WIPL-D AND HFSS

The computations assumed perfectly conducting patches with a thickness of 35μ. The substrate material RT/duroid 5880 with manufacturer's specified dielectric constant $\varepsilon_2 = 2.2(1 - i0.0004)$ and a thickness h= 1*.575mm.* Calculations were performed for a single patch radiator and a linear array of three identical patches aligned in the E-plane. Referring to Fig.1(a) the pertinent dimensions for the single patch were *L=51.22 mm*, *W=60mm*, $x_r = 0.35L$, $y_r = W/2$, *u=L+40h*, and *v=W+40h*.

The accuracy levels in WIPL were chosen to be enhanced 2 for both the current expansion and integral accuracy. In addition, double edging (finer resolution) around the patch edges were specified [2]. In HFSS, the *port* boundary condition is used. Furthermore, the *ground plane* boundary condition is used in the model. The final calculations of the field and the S-parameters depend on the precision of this mesh and hence mesh refinement is performed. The frequency of refinement was chosen in such a manner that the return loss at this frequency is expected to be 10 dB or better.

Two sets of identical patches and arrays were fabricated. A panel comprised of 35 micron (1 oz) rolled copper on both sides with RT/5880duroid 0.062" substrate sandwiched in between was used for this purpose. One side of the panel was etched to produce patch radiators with the desired dimensions while on the other side SMA flanged 50 Ohm connectors were attached with screws to ¼ inch thick copper extenders that were glued to the 35 micron copper ground plane using a highly conducting epoxy.

Fig.2 Top and bottom views of typical test patches

The top and bottom of the resulting configurations are shown in Fig.2. The return loss was measured using the HP 8722D network analyzer. The three element array was centered on a ground plane/substrate with dimensions *u=114.2 mm* and *v=304.8 mm,* as shown in Fig.3.

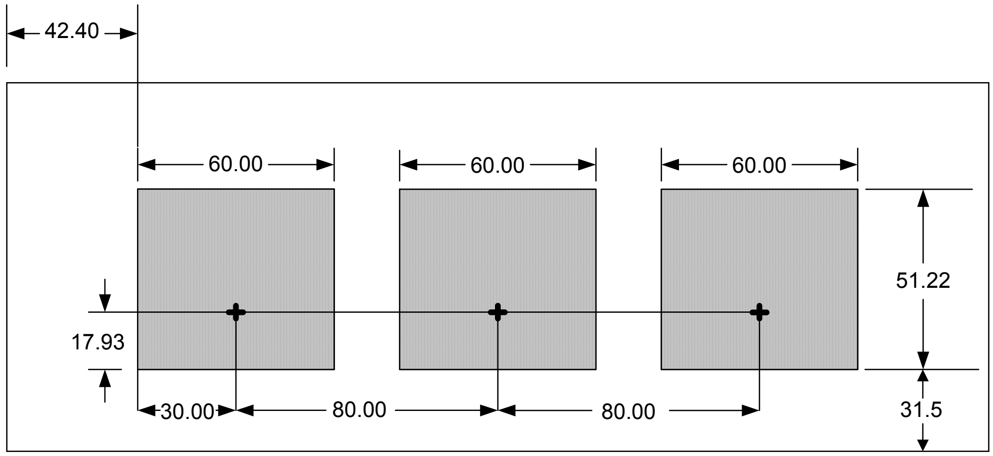


Fig. 3 3-element patch array

To test for measurement repeatability and for effects of possible dimensional deviations two sets of identical configurations were fabricated and measured. No differences were discerned in the measured return loss.
In Fig.4 (a) the plots of the return loss for the single element patch antenna computed by WIPL-D and HFSS are compared with the experimental curve. The measured results show that the patch resonates at 1910 MHz with a 30 MHz bandwidth at –10 dB points. Clearly the resonances predicted by both WIPL-D (1904 MHz) and HFSS (1886 MHz) deviate significantly from the experimental value. In addition, both WIPL-D and HFSS predicts a significantly narrower bandwidth (20 MHz vs. 30 MHz) than obtained through measurements

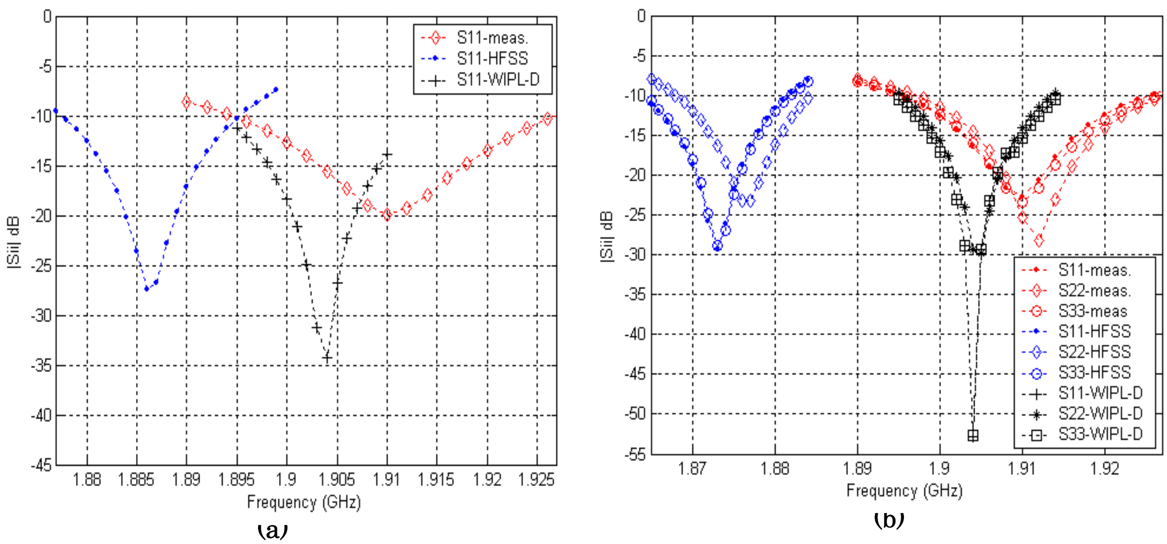


Fig.4 Return loss predicted by WIPL-D and HFSS with for a single patch, **(a)**, and 3-element patch, **(b)**, compared with experiment

Fig.4(b) compares the WIPL-D and HFSS results for a 3-element array with experiment. Note that the experimental data for the middle element shows an upward shift in the resonance frequency consistent with the behavior of the HFSS result but not with WIPLD where all elements resonate at essentially the same frequency.

The extent to which the disagreements of calculations with measurement can be attributed to deviations of the dielectric constant from its nominal value of 2.20 was investigated by carrying out the return loss computations with WIPL over the full tolerance range (2.19-2.22) certified by the vendor (Rogers Corp.) The results are plotted in Fig.5. As shown in the figure, the predicted resonant frequency varied from 1.896 GHz to 1.908 GHz (The return loss curve corresponding to the nominal value of 2.2 is indicated by the thick solid line.) However, the discrepancy of the bandwidth with measurement remained unchanged.

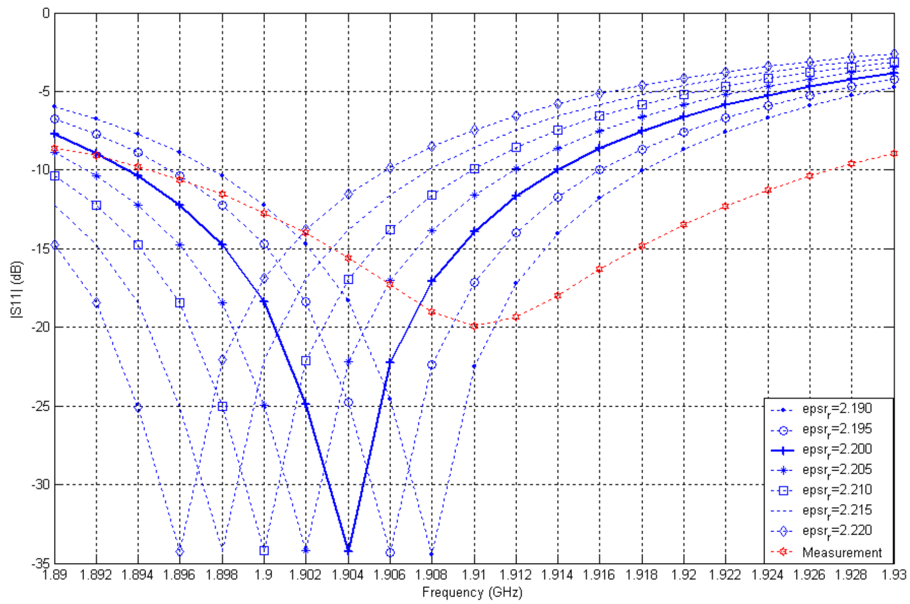


Fig. 5 WIPL calculations showing the change in the resonant frequency when the substrate dielectric constant was varied over the tolerance range certified by the vendor.

4. CONCLUDING REMARKS

The plots in Figs.4(a) and (b) show noticeable differences between by WIPL-D and HFSS modeling capabilities, with WIPL-D results marginally closer to experimental data. Nevertheless, practically these differences are inconsequential since the deviations of the calculated results from experiment for either program are too large for these software packages to constitute useful stand- alone tools for coax-fed patch antennas design.

5. REFERENCES

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