# 등가회로와 전자기장 시뮬레이션을 통해 얻은 안테나의 방사 전력의 비교 및 분석

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# COMPARISON OF ESTIMATED RADIATED POWER OF ANTENNA USING ELECTRICAL CIRCUIT AND FULL WAVE ELECTROMAGNETIC SIMULATION

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**Abstract** - Full wave electromagnetic simulation or fabricated models of an antenna are used to predict its radiation characteristics. In this work estimation of radiated power of an antenna based on its electrical model is presented. The computed radiated power using the electrical model have good agreement with the radiated power results obtained through the full wave electromagnetic simulation of the antenna model. The presented approach offers the advantage of saving of computation time of the full wave EM simulation.

## 1. Introduction

Radiation characteristics of antenna determines jts operational properties. These characteristic (radiated power, directivity and gain etc) of the designed antenna structure are estimated by simulating the designed model in 2D/3D full wave electromagnetic simulation softwares like High Frequency Structure Simulator (HFSS), Computer Simulation Software (CST) studio etc. The computed results using such simulating tools based on the numerical analysis technique gives a good estimation of the actual radiation properties of the antenna. However th estimation of radiation characteristics for a wideband frequency increase the computation time in the EM softwares. The computation time is also dependent on the geometry and meshing properties of the designed antenna model in the used numerical analysis based EM tool.

In this work radiated power estimation of dual band planer inverted F antenna (PIFA) based on its electrical lumped equivalent circuit model is presented. Lumped equivalent circuit of the designed dual band PIFA is formed using the rational approximation of its frequency domain response [1] [2]. The designed dual band PIFA is simulated in HFSS for EM simulation. The simulated admittance parameters are approximated to a rational function using the vector fitting technique. Electrical circuit of the dual band planer inverted F (PIFA) antenna is extracted from the fitted rational function. Scattering parameters and radiated power is calculated from the developed lumped equivalent circuit model. The comparison of the scattering parameters and radiated power results of electrical circuit and simulated HFSS model shows very good agreement. The presented approach is of great use for the estimation of radiation characteristics of the designed antenna structure in the wideband with much less computation time as compared to th full wave electromagnetic simulation in EM software.

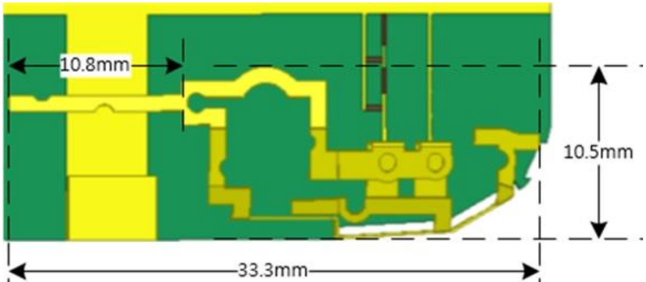
The details of the lumped equivalent circuit formulation and radiated power calculation is elaborated in the following sections.

## 2. Electrical Circuit Formulation

The simulated model of dual band PIFA is depicted in Figure 1. The designed dual band PIFA operates in GSM 900 (lower operating band) and GSM 1800 (higher operating band) bands respectively. The simulated admittance parameters of the antenna are converted to a rational function of the form (1) [1][2] using the vector fitting method.

$$f(s) = \sum_{m=1}^{N} \frac{r_m}{s-\alpha_m} + d + se \tag{1}$$

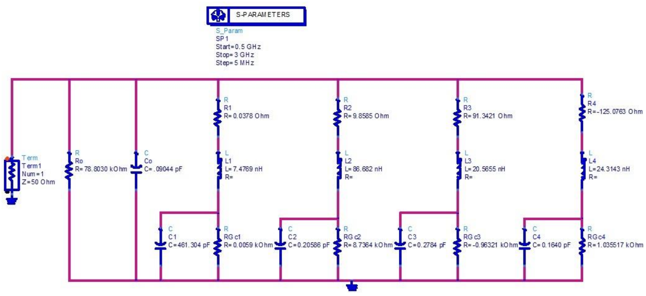
In vector fitting technique, the rational function approximation



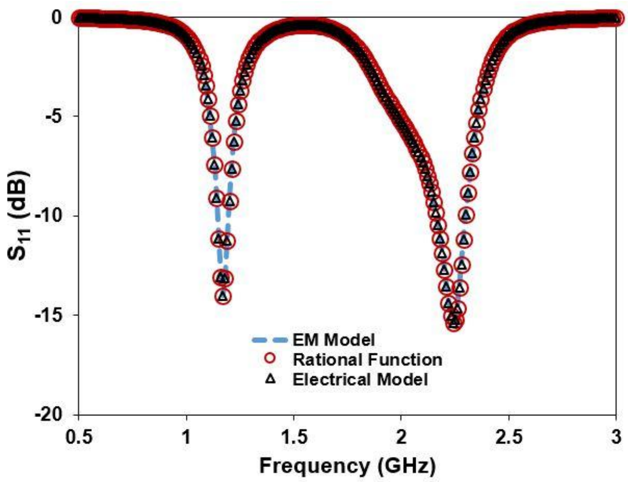

<그림 1> Designed Dual Band PIFA

procedures is started by defining some initial poles in the frequency band of the antenna [1] [3]. The technique employees the pole flipping procedures in an iterative manner until the best fitting of the input frequency response data and rational function is obtained. After that lumped equivalent circuit of the simulated antenna model can be extracted from the fitted rational function [1]. It can be noted from equation (1) that the formed equivalent circuit will constitutes of series RL and RLCG branches along with one conductance and capacitive branch. Series RL branch is formed for the defined real poles $\{\alpha_m\}$ of equation (1) while the RLCG brach relates to the complex conjugate pole pair.

All branches will be attached in parallel to each other. The number of the RL and RLCG branches are dependent on the number of the defined initial poles for the starting of the fitting process. Four complex conjugate initial poles are defined for the fitting the simulated admittance response of the designed dual band PIFA of Figure 1. The developed equivalent circuit for the designed antenna model is shown in Figure 2. Figure 2 illustrates that the formed electrical model have four RLCG branches and one resistive and capacitive branch. The element values of each electrical element can be calculated using the described procedures in [1]. The developed lumped equivalent circuit is simulated in Advanced Design System (ADS). The scattering parameter comparison of developed electrical circuit, fitted rational function and simulated HFSS model is illustrated in Figure 3. Figure 3 confirms that the computed scattering parameters using the lumped electrical circuit, fitted rational function and EM simulated model are perfectly matched.



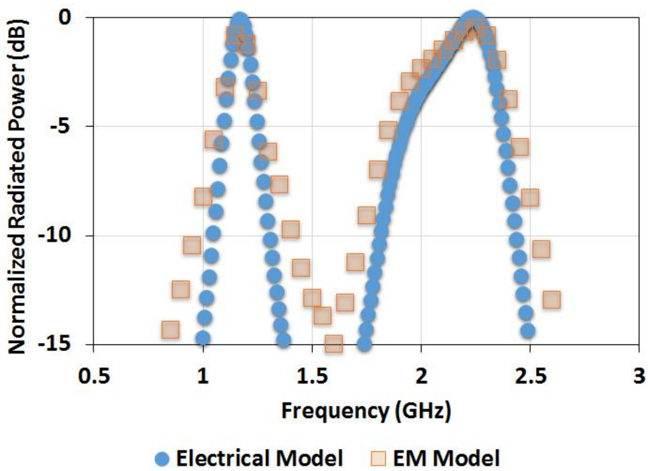

<그림 2> Electrical Model of Dual Band PIFA




<그림 3> Comparison of EM model, rational function and electrical model scattering parameters

### 3. Radiated Power Estimation

Radiated power of an electrical circuit is dependent on the power radiated by it resistive elements. The formed lumped equivalent circuit of dual band PIFA [Figure 2] constitutes of eleven resistive components. The radiated power of each resistor is computed by dividing the square of the voltage drop across each resistive elements by the resistance value. The computed radiated power of each resistive element is added to get the total radiated power of the lumped equivalent circuit. The total radiated power (RP) calculation formula is shown in equation (2).




<그림 4> Comparison of EM model and electrical model radiated power

$$RP_T = \sum_{i=1}^{N} RP_i = \frac{1}{2}\sum_{i=1}^{N}\frac{V_i^2}{R_i} \qquad (2)$$

In equation (2), $N$ is the total number of resistors in the lumped equivalent circuit and $V_i$ is the voltage drop across *ith* resistor ($R_i$). The radiated power of the electrical model is calculated in ADS. Figure 4 depicts the normalized radiated power calculated results using the electrical model and HFSS simulated model. It can be observed from Figure 4 that both results have good agrement.

The presented results shows that electrical circuit can be used to depict the various radiation characteristics of the antenna which has very close relation with the computed radiation properties using a full wave electromagnetic simulation in a much less time than the computation time of complete simulation in EM software. Also the lumped equivalent circuit can be used to perform transient analysis to depict the time domain behaviour of the designed antenna model.

### 4. Conclusion

In this work the comparison of computed radiated power using EM simulation of antenna and its developed lumped equivalent circuit is presented. Electrical circuit of the dual band PIFA is formed from the approximated rational function of its simulated admittance parameters. Radiated power of the lumped equivalent circuit is calculated by simulating the electrical model in ADS. The lumped equivalent circuit model and simulated HFSS radiated power and scattering parameters shows good agreement. The presented approach computes less time for the prediction of radiation properties of the antenna as compared to its full wave EM simulation.

### [References]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