DESIGN AND FABRICATION OF AN RF ENERGY METER PART 3: ANTENNA FOR POWER DENSITY MEASUREMENTS

D. N. Uduwawala

Department of Electrical and Electronic Engineering, University of Peradeniya

Introduction

Different applications demand different types of antennas based on frequency, bandwidth, angular coverage, polarization, gain etc. Various types of antennas ranging from simple wire antennas to sophisticated smart antennas, which can change its properties to suit the environment, have been designed for various applications.

Because of the extensive use of electromagnetic spectrum by various wireless communication systems, electromagnetic field measurements are especially needed nowadays to determine whether the signal strengths around are beyond the acceptable limits for human beings. The antenna is an essential component of such a field probe and it has to be isotropic over the frequency band of operation.

This paper describes the design and construction of an antenna for an RF energy meter operating in 300-1300 MHz. The Energy meter calculates the incident signal power density by using the signal power received at any frequency in this range. The remaining parts of the design of the meter (part 1 and 2) have been described in two separate papers in these proceedings.

Choice of the Antenna

The antennas are generally not isotropic. Therefore, the received power of an antenna depends on the direction of the incident wave and its polarization in addition to the antenna efficiency and VSWR at the feed point. Thus, in order to pick the actual power density of the incoming wave, the antenna has to be rotated in all possible directions which is a tedious and erroneous job.

The small circular loop antenna (radius $a < 0.03\lambda$) has the important property that the received power P_r is proportional to the square of the magnetic field perpendicular to the loop (Balanis, 1996). I.e.

$$P_r \propto H_z^2 = H^2 \cos^2 \alpha \sin^2 \theta. \qquad (1)$$

(See Figure 1). Therefore, the sum of received powers obtained by placing the loop in three orthogonal planes is proportional to the actual power density *Savg* of the incoming wave (assuming plane waves) irrespective of its direction. I.e.

$$P_r^{total} \propto (H_x^2 + H_y^2 + H_z^2). \qquad (2)$$

$$\therefore P_r^{total} \propto S_{avg}. \qquad (3)$$

In other words, three loop antennas placed orthogonally to each other forms an isotropic antenna provided loop radius $a < 0.03\lambda$. Therefore, this is the right choice of antenna for field measurements. As the first step, one loop antenna will be constructed and the incident signal power density is calculated using the power measurements obtained by placing the loop in three orthogonal planes.

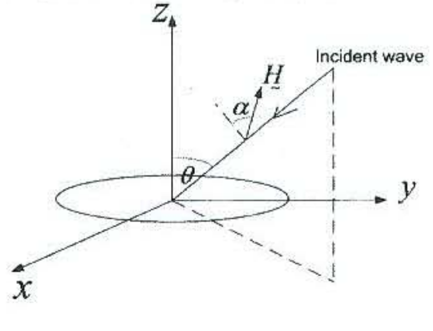

Figure 1. Wave incident on a loop antenna with arbitrary polarization and direction.

By calibrating the meter the incident power density can be calculated. Theoretically, the proportionality constant can be shown to be

$$k = \frac{3\lambda^2}{8\pi} \frac{R_r}{R_r + R_l}(1 - |\rho_r|^2) \qquad (4)$$

where λ is the wave length, R_r is the radiation resistance, R_l is the loss resistance and ρ_r is the reflection coefficient at the feed point. For a small loop, all these parameters can be explicitly calculated.

For the frequency range of operation 300-1300 MHz, the required loop radius is 0.6 cm. The standard method to construct the loop antenna is to integrate the balun into the loop itself (Kraus *et al*, 2002) as shown in Figure 2. The loop can be made of a bare-copper semi-rigid coaxial cable with a suitable diameter, for example 0.047 mils which is commercially available.

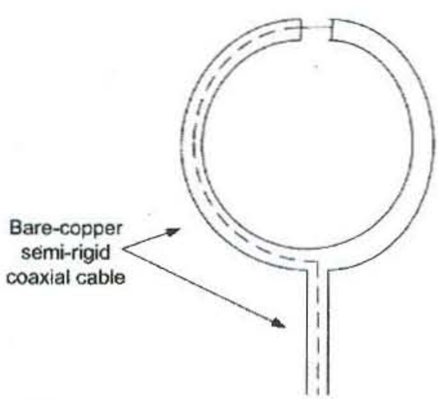

Figure 2. Loop antenna.

Characteristics of the antenna: Analytical and simulation results

Loop antenna characteristics are obtained both analytically and from simulations. The simulations results are obtained by using the commercially available electromagnetic solver HFSS (High Frequency Structure Simulator). Figure 3 shows the characteristics of the loop. Figure 4(a) shows the variation of the inverse of the proportionality constant ($1/k$) with frequency. The corresponding power density component (one of the three components) can be calculated from Figure 4(a) as given below.

$$S_{avg}^{x/y/z} = P_r.(\frac{1}{k}). \qquad (5)$$

The receiver is designed so that minimum power level at the receiver input is 110 dBm. Therefore the minimum detectable power density of the meter can be calculated from Figure 4(a) and it is plotted in Figure 4(b). These power density values are well below the practical values of typical transmitters. Eg.: power density of the field created by a mobile phone radiating 2 W of power at a distance of 1 km is 159 nW/m2.

Conclusion

Design of an antenna for an energy meter operating in the frequency range 300-1300 has been described. The antenna is a loop antenna of radius 0.6 cm. Its suitability for this particular application has been justified by using both analytical and simulation results. The method of construction of the antenna and how it can be used for power density measurements have also been described. The next step is to construct the antenna using a semi-rigid bare-copper coaxial cable assembly and calibrate the antenna. The purchase of bare copper semi-rigid cables has been on hold due to lack of funds.

References

Balanis, C.A. (1996). Antenna Theory: Analysis and Design, Second Edition, John Wiley and Sons Inc.

Kraus J. D., Marhefka R.J. and Khan A.S. (2002). Antennas for All Applications, Third Edition, Tata Mcgraw-hill Publishing Company Ltd.

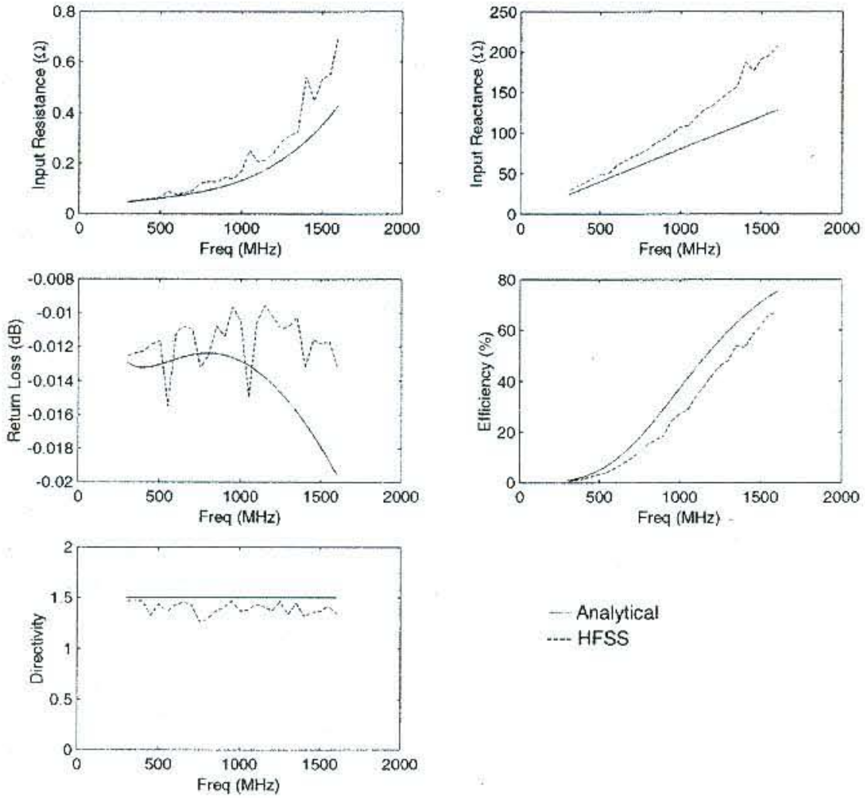

Figure 3. Variation of typical parameters of the designed loop antenna with frequency.

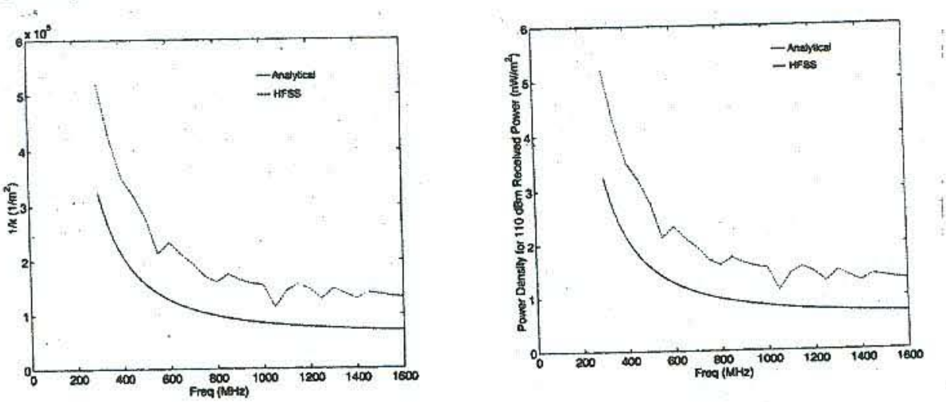

Figure 4. (a) Variation of $1/k$ with frequency. (b) Variation of sensitivity with frequency.