

ESTIMATION OF ANTENNA FACTOR OF MICROSTRIP PATCH ANTENNA AS EMI SENSOR

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Abstract—This paper presents the result for antenna factor of microstrip patch antenna when used as electromagnetic interference (EMI) sensor. Antenna factor is an important parameter of a sensor used for EMI measurements. The microstrip antenna has found wide application as transmit and receive antenna in modern microwave systems. In this paper, a new application of microstrip antenna as EMI sensor is presented. The result for antenna factor versus frequency of a microstrip patch antenna is presented using commercial software CST Microwave Studio. Also the experimental results for a prototype antenna are presented and compared with the simulated result.

1. INTRODUCTION

The electromagnetic interference (EMI) has become an increasingly crucial issue in the modern era of high speed, high density electronic equipment. This necessitates the measurement of radiated emission and susceptibility of these equipments. The measurement is performed using EMI sensors. The commonly used EMI sensors are different wire antennas [1–5] for frequencies up to 2 GHz and rectangular waveguide and thick windows for frequency above 2 GHz [6, 7]. The important features of microstrip antenna e.g., low-profile, low-weight, low-cost, easy integrability into arrays or with microwave integrated circuits have made it popular as transmit and receive antenna in modern microwave systems. Numerous researchers had worked on different applications of planar microstrip structures [8–12]. However, the authors have not noticed any work reported on the performance evaluation of microstrip patch antenna as EMI sensor. The use of this antenna may be a

useful alternative to the heavy waveguide structures as EMI sensors. This paper presents the initial investigation on the performance of this antenna as EMI sensor in terms of the antenna factor. The ratio of incident electric field at the surface of the sensor to the received voltage at the antenna terminal when terminated in $50\ \Omega$ load is known as antenna factor [13]. The results have been achieved as the output of the commercial software CST Microwave Studio [14]. Also the prototype antenna is fabricated and the experimental data is presented for comparison. The results show well agreement.

2. ANTENNA FACTOR

The most common performance descriptor of an EMI sensor is its antenna factor. When an antenna is used as an EMI sensor, it is exposed to an electromagnetic field. This incident field generates a voltage at the antenna terminal, which is read on the receiver/spectrum analyzer. The antenna factor is the factor by which one would multiply the output voltage of a receiving antenna to obtain or recover the incident electric field. The ratio of incident electric field on the surface of the sensor to the received voltage at the antenna terminal when terminated by $50\ \Omega$ load is known as antenna factor [13]

$$\text{antenna factor} = (\text{incident electric field } (E_i)) / (\text{received voltage } (V)) \quad (1)$$

Here E_i is the incident electric field with the polarization giving maximum output and V is the output voltage developed across the load.

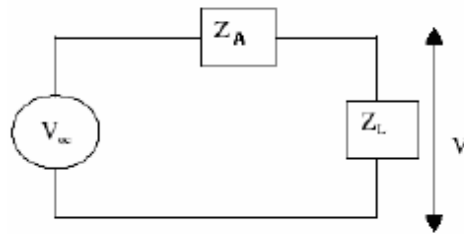


Figure 1. Equivalent circuit diagram of an EMI sensor.

The most published antenna factors are defined assuming the antenna is connected to a $50\ \Omega$ load. The Thevenin's equivalent circuit diagram of an EMI sensor is shown in Fig. 1. The receiving antenna is

replaced by an equivalent open circuit voltage V_{oc} at the two terminals of the antenna and its impedance Z_A . The open circuit voltage V_{oc} at the gap of the antenna is related to the incident electric field on the antenna surface.

3. ANTENNA CONFIGURATION

The geometry of the patch antenna, which is illuminated by a plane wave, is shown in Fig. 2. The dimensions are calculated for resonant frequency 2.8 GHz following the formulae available in literature [15].

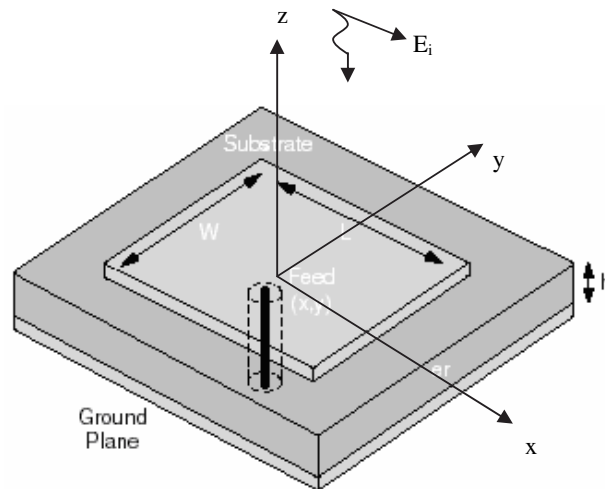


Figure 2. Patch antenna illuminated by plane wave.

Here W = width of the patch
 L = Length of the patch
 h = height of the substrate
 (x, y) = position of feed
 ϵ_r = permittivity of the substrate

4. SIMULATION RESULTS

The dimension of the antenna used for the simulation and also verified with measured results is shown in Fig. 3. Here height of the substrate is taken as 0.1588 cm and ϵ_r equals to 2.5. For the simulation of the fabricated patch antenna the 3-D electromagnetic solver Computer Simulation Technology Microwave Studio (based on FIT) is used [14].

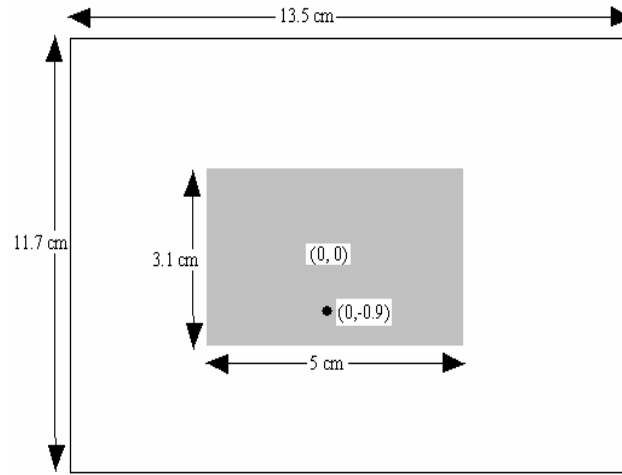


Figure 3. Dimensions of fabricated patch antenna.

For the simulation of antenna factor, the antenna is illuminated by a plane wave normally incident on the patch. The antenna factor is evaluated from the voltage developed across the $50\ \Omega$ load connected at the antenna terminal.

5. EXPERIMENTAL RESULTS

An S-band microstrip antenna (Fig. 4) is used as a probe to sense the electric field radiated by an S-band horn. First, a measured amount of power at the chosen frequency is radiated by the transmitting horn, excited by a signal generator. The sensor, in this case, a patch, is aligned to receive the transmitted field in the flat lobe of the transmitting antenna's radiation pattern. The strength of the electric field at the plane of the patch antenna is calculated using well-known relations, and the received power is measured by a Spectrum Analyzer. Since, the standard gain horn is not available over the frequency range of interest, initially, two identical horns are used — one as the transmit antenna and the other as the receive antenna — to determine the gain of the horns by the two antenna method of measurement. Ideally speaking, the antenna factor of any probe should be measured in Anechoic or Semi-Anechoic Chamber to limit the influence of undesired echoes in the frequency band of interest. In the experiment conducted, this effect is minimized by using microwave absorbers in the vicinity of the transmitting and receiving antennas,

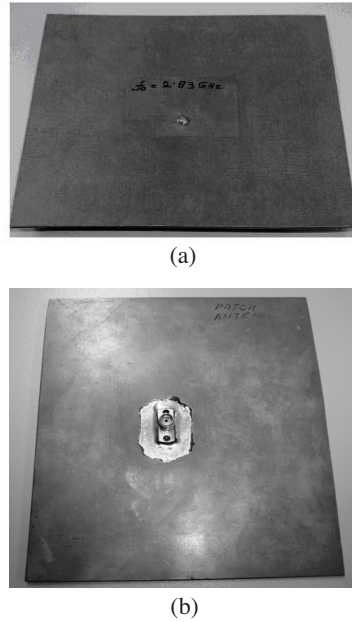


Figure 4. Fabricated patch antenna (a) Top view; (b) Bottom view-coaxial probe feed.

and by using a Spectrum Analyzer to measure the received power at the frequency of measurement.

A S-band horn (inside dimension $7.214 \text{ cm} \times 3.404 \text{ cm}$; outside dimension $26.5 \text{ cm} \times 221 \text{ cm}$) is used. The experiment is carried out over the frequency range of 2 GHz to 3 GHz, with the microstrip patch as sensor. The loss due to transmit and receive antenna-side cables are first determined using the HP 8757C Scalar Network Analyzer. The gain G , of the transmitting horn is determined by using two identical horns as transmit and receive antenna respectively and measuring their power by spectrum analyzer. The gain of the horn is calculated by using the following equation:

$$G = (4\pi R/\lambda) \cdot (P_R/P_T)^{1/2}. \quad (2)$$

where P_T and P_R are the transmitted and received power respectively and R the distance between the two identical horns. In the experiment performed, R is kept equal to 195.6 cm. The data for determination of cable loss and gain of the horn are presented in Tables 1 and 2 respectively.

Once the calibration is over, the transmitted power and the power

Table 1. Calibration for cable loss.

Frequency (GHz)	Cable loss CL_{Tx} (dB)	Cable loss CL_{Rx} (dB)	Transmitted Power P_T (dBm)
2.1	0.8	0.2	12.2
2.2	0.9	0.19	12.1
2.3	0.7	0.2	12.3
2.4	0.6	0.18	12.4
2.5	0.7	0.3	12.3
2.6	1.2	0.2	11.8
2.7	1.0	0.19	12.0
2.8	1.1	0.3	11.9
2.85	1.0	0.2	12.0
2.9	1.2	0.19	11.8
2.95	1.2	0.3	11.8
3.0	0.9	0.2	12.1
3.1	1.0	0.17	12.0

Table 2. Calculation of gain of transmitting antenna.

Frequency (GHz)	Power received by horn (dBm)	$20 \log \left(\frac{\lambda}{4\pi R} \right)$ dB	Gain of horn G (dB)	Field strength at plane of sensor (V/m)
2.1	-36.22	-44.71	-3.71	0.33
2.2	-32.96	-45.11	0.053	0.51
2.3	-28.74	-45.49	4.46	0.86
2.4	-28.16	-45.86	5.31	0.96
2.5	-27.92	-46.22	6.0	1.03
2.6	-26.95	-46.56	7.81	1.19
2.7	-25.53	-46.89	9.36	1.46
2.8	-22.84	-47.21	12.47	2.07
2.85	-14.94	-47.36	20.42	5.23
2.9	-15.77	-47.51	19.94	4.84
2.95	-15.72	-47.66	20.14	4.95
3.0	-14.82	-47.81	20.88	5.58

received by the sensor was measured using a Agilent CSA N1996 A-503 Spectrum Analyzer. Loss due to the connecting cables is taken into account. The field strength at the plane of the sensor placed at a distance d from the transmit antenna for normal incidence is obtained from the following equation

$$E = (60P_T G)^{1/2} / d \text{ V/m.} \quad (3)$$

The voltage at the sensor terminals, V_M , is calculated from the measured power, P_M assuming a measuring device with an input impedance of 50Ω for the Spectrum Analyzer, as follows

$$V_M = (50P_M)^{1/2}. \quad (4)$$

The antenna factor (AF) is then evaluated as follows

$$AF = |E|/V_M \text{ m}^{-1} \quad (5)$$

$$= 20 \log_{10} (|E|/V_M) \text{ dB m}^{-1}. \quad (6)$$

The return loss of the patch antenna is measured using scalar network analyzer. The experimental and simulated results of return loss are presented in Fig. 5. The antenna factor versus frequency plot is shown in Fig. 6.

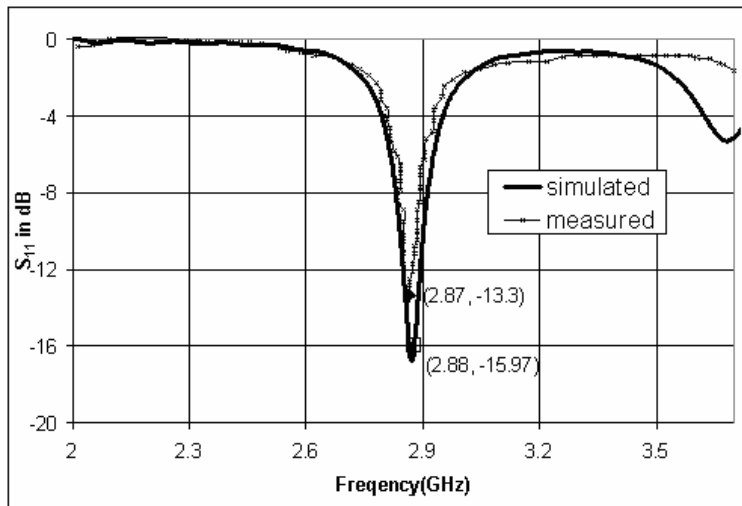


Figure 5. Return Loss in dB versus frequency of microstrip patch antenna.

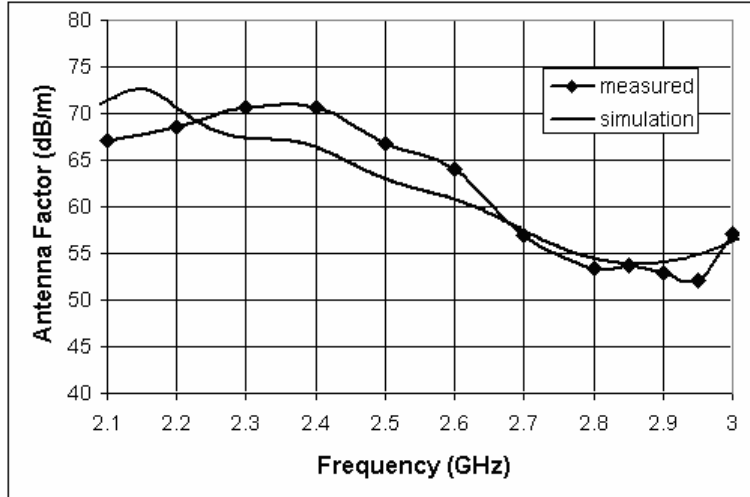


Figure 6. Antenna factor in dB/m versus frequency of microstrip patch antenna.

6. DISCUSSIONS

The measured data of return loss of the microstrip patch antenna shows well agreement with the simulated result (Fig. 5). Also the measured and simulated antenna factor data shows the same pattern over the frequency band of interest, though a maximum difference of ~ 6 dB is noticed (Fig. 6) at some frequency points. The possible reasons for this deviation in measured and simulated results are summarized as follows:

- The mismatch produced by the cables on transmit and receive side will contribute to the measurement error significantly.
- Though the scattering by other reflecting bodies in the vicinity are tried to minimize, can not be removed totally.
- Errors in calibrating the horn, cables, orienting the sensor with respect to the transmitting horn may incorporate error in the measured values of antenna factor.

The antenna factor versus frequency plot shows that the designed antenna behaves as a good sensor at this frequency range. This antenna may be a useful alternative to the heavy waveguide structures as EMI sensors. Though the major limitation with such an approach is the narrow band performance of this antenna, this study may be extended for other microstrip antennas with broadband characteristics [16–19].

Also further study is required for the near field correction to the antenna factor of the patch antenna.

7. CONCLUSION

A very interesting application of microstrip patch antenna as EMI sensor is presented. The antenna factor of this antenna over a frequency range is evaluated for an incident EM radiation from a distant antenna. The simulated result shows same trend as the experimental data. The result for antenna factor of the patch antenna encourages the application of this antenna as EMI sensor.

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