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The Studies on Different Scaling Factor for Microstrip Antenna Design

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Abstract - This paper had studied the effect of different scaling factor (τ) to microstrip log periodic antenna. Two value of scaling factor (τ) 1.02 and 1.05 had been studied. The bandwidth of the antenna has increase from 10.65 % to 23.92 % as bigger scaling factor were used. Five element antennas were applied in both designs. The simulation for the five elements was done using circuit simulator. The etching technique was applied in the fabrication process by using the FR4 microstrip board with dielectric constant 4.7 and loss tangent is 0.019. The properties of antenna such as bandwidth, gain, cross-polar isolation and half power beamwidth have been investigated and compared between simulation and measurements.

1. Introduction

The idea of the microstrip antenna date's back to the 1950's[1],[2], but it was not until 1970's that serious attention was given to the element. After more than a decade, development of microstrip antennas on the orther hand is relatively more mature. Microstrip antennas and antenna arrays are being used in many applications such as WLAN, RFID, point to point wireless communication and etc. With the exception of a thick substrate, the bandwidth of a microstrip antenna is generally narrow [3] [4].

Wireless communication has been developed rapidly in the past decade and it has been already dramatic impact in our life. In the last few years, the development of wireless local area networks (WLAN) represented one of the principal interests in the information and communications field. WLAN takes advantage of a license free frequency bands, Industrial, Scientific and Medical (ISM) bands which have frequency span is from 2.412 GHz to 2.482 GHz and from 5.15 GHz to 5.825 GHz [5].

Furthermore, many Internet Service Providers (ISPs) looks convenient to apply 802.11 based point-to-point links in order to provide the wireless coverage of the *last mile* towards the client. Thus, specific antenna system was recently developed to comply with requirements dictated by such applications. Specifically, low-cost solutions for antenna design are becomes critical and required since both market and technology are so far ready to mass production [6].

Microstrip antennas have attractive features such as light weight, small volume low profile and low production cost which widely have been researched and developed in the recent twenty years [7-10]. However, microstrip antenna has a limitation which is the narrow bandwidth of the basic element. The bandwidth of the basic patch antenna is usually 1 – 3%. The bandwidth of the antenna is defined as the range of the frequencies, over which the performance of the antenna with respect to some characteristic conforms to a specific standard. The bandwidth of the antenna depends on the patch shape, dielectric constant, the thickness of the substrate and the resonant frequency [11]. The design of microstrip antennas suitable for new WLAN to achieve dual-frequency or multi-band is developed in recent years [12][13].

2. Antenna Design

The design principle for log periodic antenna requires scaling of dimensions from period to period so that performance is periodic with the logarithm of the frequency. This principle can be applied to an array of patch antennas. The patch length (L), the width (W) and Inset (I) are related to the scale factor τ by.

$$\tau = \frac{L_{m+1}}{L_m} = \frac{W_{m+1}}{W_m} = \frac{I_{m+1}}{I_m} \qquad (1)$$

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A single element of rectangular or square geometry as shown in figure 1 can be designed for the lowest resonant frequency using transmission line model. The value of L, W and I can be found through equation (2) – (10) from [14].

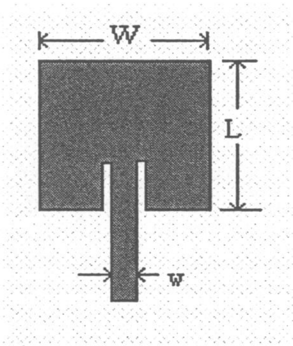

Figure 1: Square patch antenna.

Calculation of design parameters for square patch microstrip antenna is shown in table 1 and table 2 for τ=1.02 and τ=1.05 respectively. The substrate used is FR4 with dielectric constant of 4.7 and height of 1.6 mm. The loss tangent of material is 0.019 and the scaling factor $\tau = 1.02$.

Table 1: Design parameter for 5 elements LPA for τ = 1.02.

Data file (f_m)	Freq (GHz)	W=L (mm)	I_m (mm)	d_m (mm)	R_{in} (50 Ω) (mm)
f_1	2.325	30.07	16.30	31.75	11.69
f_2	2.375	29.44	15.96	28.00	11.42
f_3	2.422	28.82	15.63	32.80	11.21
f_4	2.475	28.24	15.31	27.20	10.96
f_5	2.526	27.60	15.00	32.10	10.72

Table 2: Design parameter for 5 elements LPA for τ = 1.05.

Data file (f_m)	Freq (GHz)	W=L (mm)	I_m (mm)	d_m (mm)	R_{in} (50 Ω) (mm)
f_1	2.26	30.813	16.741	30.505	10.03
f_2	2.38	29.346	15.944	27.32	9.556
f_3	2.49	27.948	15.185	23.48	9.101
f_4	2.62	26.618	14.462	20.87	8.668
f_5	2.75	25.350	13.773	28.781	8.255

The distance (d) between element (m) and element (m+1) is determine according to the nest higher frequency element of the antenna. The input looking into the next higher frequency must be high impedance before the next element (m+1) is connected to the schematic diagram. The distance between two patch antennas is not necessarily half wavelength and varying log periodically. While, the microstrip antenna feed line is a quarter wavelengths long [14].

Each element is being simulated through momentum simulation using Agilent ADS. The S parameter of these elements will be combined into the layout circuit element as shown in figure 2.

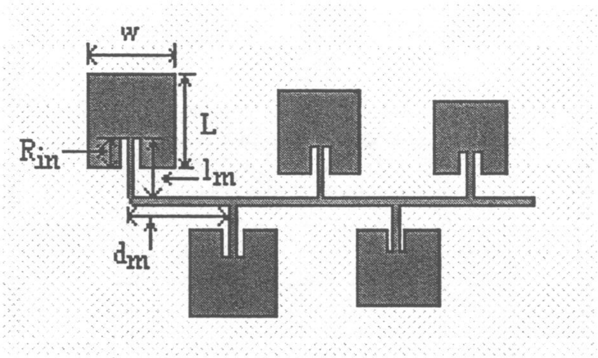

Figure 2: Layout for 5 element LPA.

The inset feed distance of the microstrip antenna is chosen for 50 Ohm input impedance and it is scaled periodically. In general, the design of log periodic microstrip antenna can be carried out as follows [14]:

(a) Choose the first resonance frequency and scale it periodically for the subsequent resonance frequencies.
(b) Calculate the patch dimension (W=L) for square patch antenna and the inset feed dimensions for input impedance of 50 ohm at resonance and scale log periodically for the next patch.
(c) The distance between the branch lines are determined so that the input impedance looking into the next higher frequency is high impedance.

3. Result and Discussion

The result of log periodic antenna for both scaling factor is discussed in term of bandwidth response, radiation pattern characteristic and cross polar isolation. The comparison between measurement and simulation for return loss is also discussed.

3.1 Input Return Loss

The measurement and simulation result of input return loss for 5 elements LPA is shown in figure 3 and figure 4. For the τ = 1.02 the bandwidth from the measurement result is 10.75 % and the bandwidth using simulation result is 10.43%. While for τ = 1.05, the bandwidth from the measurement result is 23.92% and the band width using simulation is 23.72%. The experimental result show the frequency has been shifted up by 165.9 MHz for τ = 1.02 and 83 MHz for τ = 1.05. The resonance of the antenna can be seen by observing the dip in the return loss. There is a close agreement between the simulation and measurement result for the bandwidth. The bandwidth for τ = 1.05 is much broader compared to τ = 1.02.

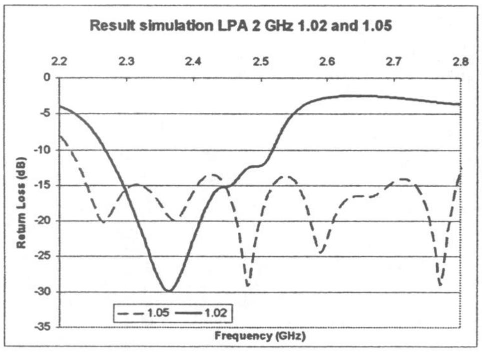

Figure 3: Result simulation for τ=1.02 and τ=1.05.

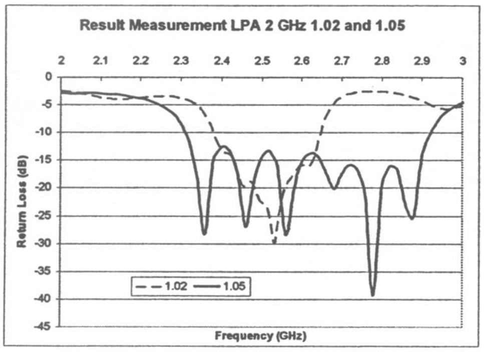

Figure 4: Result measurement for τ=1.02 and τ=1.05.

3.2 Radiation Pattern

Figure 5 and figure 6 shows the radiation pattern of the LPA antenna for E Plane and H Plane at 2.4 GHz. The radiation pattern is in the broadside direction. In the E Plane the pattern has the narrow beam compared to the H Plane. The cross polar isolation for E Plane is 16.42 dB and for H Plane is 18 dB for τ = 1.02. While the cross polar isolation for E Plane is 12.43 dB and for H Plane is 15.05 dB for τ = 1.05. The cross polar isolation for smaller scaling factor is better than larger scaling factor value. The HPBW for E Plane is 41° and H Plane is 77° for τ = 1.02. While, The HPBW for E Plane is 93° and H Plane is 52° for τ = 1.05.

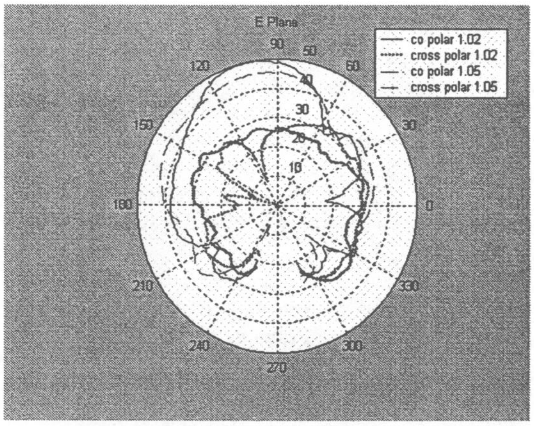

Figure 5: Radiation pattern for E Plane.

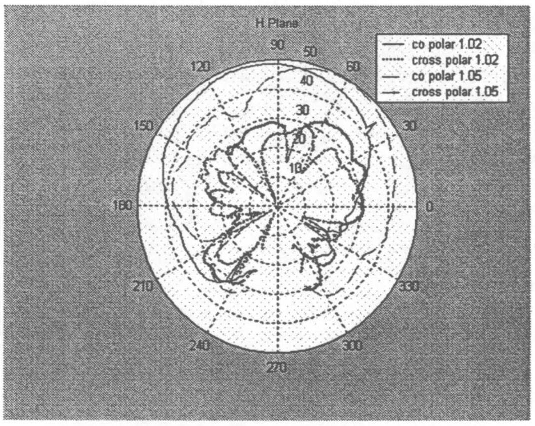

Figure 6: Radiation pattern for H Plane.

4. Conclusion

The bandwidth for LPA with τ =1.05 is 13.17% greater than bandwidth for LPA with τ = 1.02. The cross isolation of the log periodic antenna for both τ value is in the range 12 to 19 dB. The maximum cross-polar isolation can be seen at E Plane. The

HPBW for the LPA is 93° for E Plane with $\tau = 1.05$ and 77° for H Plane with $\tau = 1.02$. The LPA with $\tau = 1.05$ had offered wider bandwidth and better return loss compared to LPA with $\tau = 1.02$.

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