Design of a Broadband Smart Antenna

A. A. Sulaiman[1], M. F. Ain[1], S. I. S. Hassan[1], A. Othman[1], M. A. Othman[1], R. A. Majid[1], M. Z. Saidin[1], M. H. A. Hamid[1], N. I. Ali[2], M. H. Jusoh[2], Z. I. Khan[2], N. H. Baba[2], R. Awang[2], Z. Awang[2], M. Isa[3], M. Yahya[4]

[1]School of Electrical & Electronic Engineering, Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Pulau Pinang, Malaysia, email: asari100@yahoo.com

[2]Faculty of Electrical Engineering, Universiti Teknologi Mara Malaysia, 40450 Shah Alam, Selangor, Malaysia

[3]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[4]Telekom Research, Development and Innovation Centre, Lingkaran Teknokrat Timur, 63000 Cyberjaya, Selangor, Malaysia

This paper described the design, simulation and fabrication of a broadband microstrip smart antenna. The smart antenna is a combination of seven element log periodic antenna with two bandpass filters. The log periodic antenna provides a wideband of 700 MHz. The filters operate at the best value of 5.3 GHz and 5.74 GHz with return loss at these frequencies -24.43 dB and -27.864 dB. The smart antenna was designed and simulated using *GENESYS* and measured using Scalar Network Analyzer (SNA). The measurement results agree well to with the results from simulation.

1. Introduction

A smart antenna is an antenna that modifies it's received or transmit characteristic in order to enhance the antenna's performance. Commonly smart antenna is composed of two or more antennas. The upcoming wireless local area networks (WLAN) standard at 5 GHz to 6 GHz are interesting candidates to apply smart antenna principles. The smart antenna also required in radar and communications systems such as Synthetic Aperture Radar (SAR), dual-band for Global System Mobile communications (GSM) and Global Positioning System (GPS) [1]. The application of this antenna can help provide high data rates, increase channel capacity and improve quality of service at an affordable cost [2]. A smart antenna consists of combination between a log periodic antenna and two bandpass filters was the main focus in this project. Two different methods of designs were required to perform a complete system of the broadband smart antenna. All elements have been fabricated on the same substrate that have relative dielectric constant, $\varepsilon_r = 2.33$, dielectric loss tangent of 0.001 and substrate thickness of 0.5 mm.

2. Methodology

The patch width and actual patch length for single element antenna can be calculated such as [3]. Important parameters such as effective dielectric constant ε_{reff}, effective length L_{eff} and extra length (ΔL) were also calculated. The basic concept of log periodic antenna is gradually expanding periodic structure array. It involves the scaling of the dimensions of the antenna from period to period so that the performance was periodic with the logarithm of the frequency. The patch length and width can be related to the scale τ. In this case value of τ is equal to 1.05. The scale related to the length and width of this antenna is shown in the equation 1.

$$\tau = \frac{L_{m+1}}{L_m} = \frac{W_{m+1}}{W_m} \tag{1}$$

The distance between element m and the element m+1 was determined according to the nearest higher frequency element of the antenna. The input looking into the next higher frequency must be high impedance before the next element m+1 was connected to the schematic diagram. The distance between two patches was not necessary to be half wavelength and varying log periodically. While, the microstrip antenna feed line was quarter wavelength long [3].The basic design of the log periodic antenna can be designed by performing a single element of rectangular geometry using microstrip line feed as shown in figure 1.

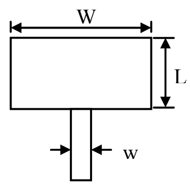

Figure 1: Simple Rectangular Patch Antenna

The lowest frequency was selected as the first patch and scaled periodically for the subsequent resonance frequency. The patch dimension needs to be calculated and scaled log periodically for the next patches toward the higher frequencies. The distance between the band lines were determined by looking to the next higher frequency which was higher impedance. Table 1 shows the design parameters that have been calculated for seven element log periodic microstrip antenna.

Table 1: Parameters for Seven Log Periodic Patches

Patch Antenna	Freq (GHz)	Width, W(mm)	Length, L (mm)	d (mm)
f_1	5.000	23.250	18.808	22.860
f_2	5.143	22.604	18.263	22.026
f_3	5.286	21.992	17.748	21.237
f_4	5.429	21.413	17.259	20.489
f_5	5.572	20.864	16.797	19.781
f_6	5.715	20.342	16.353	19.107
f_7	6.000	19.375	15.540	17.860

Seven layouts of the log periodic patches were shown in figure 2. The dimensions of the antenna were such as the value stated in table 1. In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure [5].

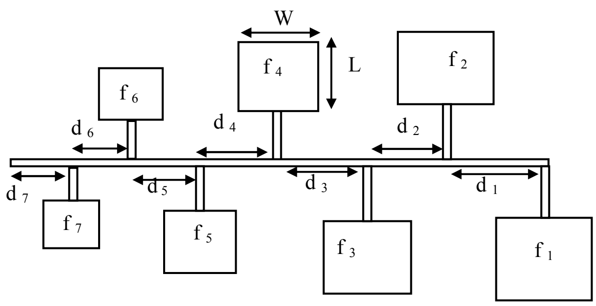

Figure 2: Layout of the Seven Elements of Log Periodic Antenna

Two bandpass filters were designed based on specific target of cut-off frequency at 5.3 GHz and 5.8 GHz with 10% bandwidth using the third order (n = 3) order of 1.0 dB Tschebychev topology [4-5]. The value of characteristic impedance and the coupling factor can be used to determine the dimension of the bandpass filter. The dimension of bandpass filter at 5.3 GHz and 5.8 GHz can be obtained from Line Cal Program using *Libra*. The microstrip width, length and spacing dimension were shown in Table 2. After all the calculation and the dimension have been gathered the bandpass filter can be simulated.

Table 2: Design Parameter of Bandpass Filter

Freq (GHz)	Z_o (Ω)	C (dB)	Width (mm)	Length (mm)	Spacing (mm)
5.3	50	-19.10	1.40	10.14	0.60
	52.05	-11.75	1.18	10.32	0.17
	50.31	-19.22	1.39	10.14	0.61
	50.31	-19.22	1.39	10.14	0.61
	52.05	-11.75	1.18	10.32	0.17
	50	-19.10	1.40	10.14	0.60
5.8	50	-19.10	1.40	9.27	0.60
	52.05	-11.75	1.18	9.43	0.17
	50.31	-19.22	1.39	9.27	0.61
	50.31	-19.22	1.39	9.27	0.61
	52.05	-11.75	1.18	9.43	0.17
	50	-19.10	1.40	9.27	0.60

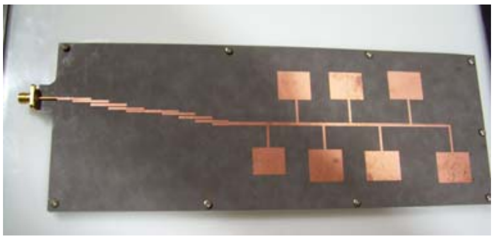

Figure 3: Broadband Microstrip Smart Antenna

Fabrication process start after simulation result achieved the aim. The antennas can be integrated with other circuit to produce an integrated microstrip subsystem. Microstrip antennas have the advantages such as low profile, light weight, low cost, conformability and ease of fabrication and integration RF devices [1]. The simulation layouts were fabricated on RT Duroid. Figure 3 show a fabricated broadband microstrip smart antenna that has been designed according the specification of single log periodic antenna and two bandpass filters.

3. Result & Discussion

Result of this project was projected in two parameters from simulation and measurement result. The focus results were VSWR and return loss. The return loss evaluates the difference between the reflected wave and the incident wave in decibels [6-7]. Figure 8 shows the return loss for log periodic antenna. This antenna was designed within a range of 5 GHz to 6 GHz, The highest resonant of return loss is at 5.48 GHz with a value of -25.72 dB and a bandwidth about 700 MHz.

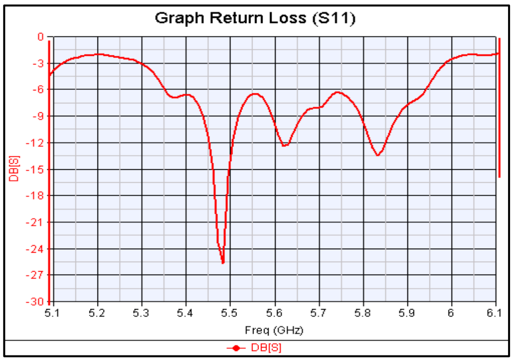

Figure 4: Return Loss of the Seven Patch Log Periodic Antenna

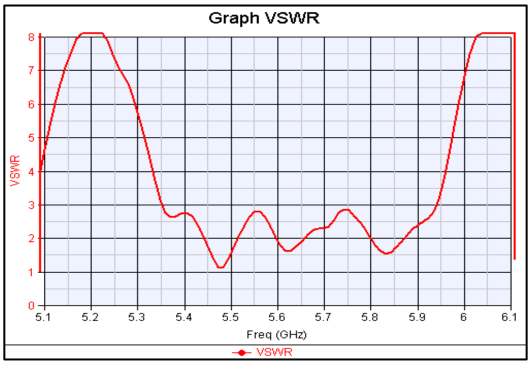

Figure 5: VSWR of Seven Patch Log Periodic Antenna

Figure 5 shows the result of VSWR for log periodic antenna. The target for this designed is to get the value of VSWR less than 2. The aim was achieved at certain point in the graph especially at 5.48 GHz, 5.62 GHz and 5.83 GHz with VSWR of 1.109, 1.627 and 1.532 respectively.

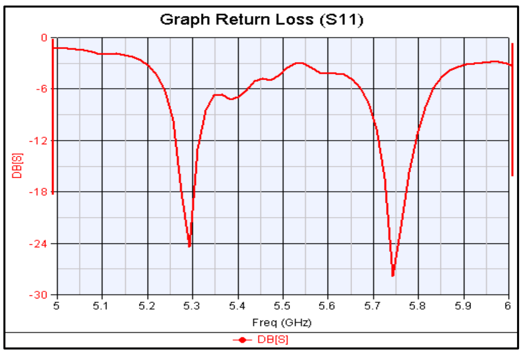

Figure 6: Return Loss of the Smart Antenna

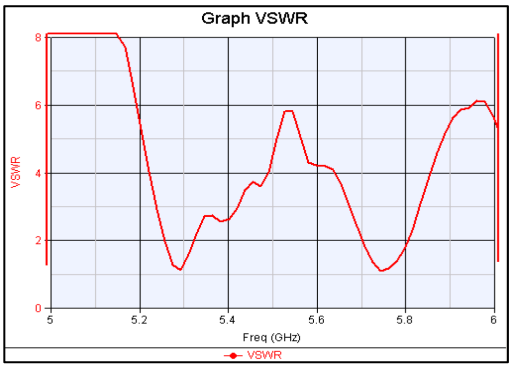

Figure 7: VSWR of the Smart Antenna

Two bandpass filters were designed to combine with the broadband antenna. The combinations of two different frequencies were very important because the result of both filters will perform a broadband smart antenna.The combination of log periodic antenna have been simulated from 5 GHz to 6 GHz with two bandpass filters that have been designed at center frequency of 5.3 GHz and 5.8 GHz. Figure 6 show that the frequency resonate at 5.3 GHz with value of return loss -24.43 dB and another one resonate at 5.74 GHz with return loss -27.864 dB. Figure 7 show the VSWR of the complete combination. The value of VSWR at 5.3 GHz was 1.112 while at 5.74 GHz was 1.224. The result has been measured using Hewlett Packard 8757D a scalar network analyzer and 83640B Sweep Generator. In the process of calibration and measurement the device under test which in this case was the broadband antenna connected to obtain actual output from the fabricated device.

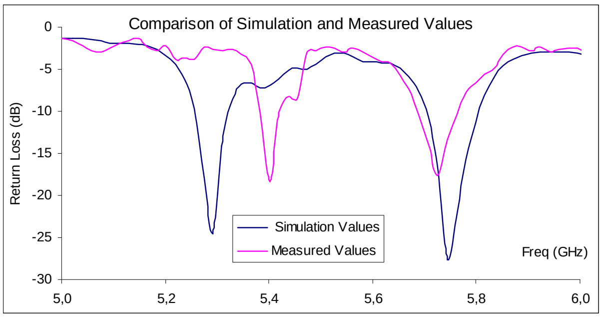

Figure 8: Simulated and measurement result of broadband smart antenna

Simulation and measured data have been combined together in figure 8. There were similarity of the shape and pattern of both results. However, the measured value has been shifted slightly. The value of return loss at 5.3 GHz has changed to 5.4 GHz as it shifted to the right with a value of -18.402 dB while 5.8 GHz was shifted slightly with the value of –17.594 dB. The best VSWR values in measurement result were 1.149 and 1.1205 respectively. The differences were due to several factors. At high frequencies the signals tend to radiate into space giving rise to losses. In this project a microstrip was used to design the smart antenna. A microstrip is an asymmetric transmission line structure and is often used in unshielded or poorly shielded circuits where any radiation is either free to propagate away or to induce currents in the shielded box. This behavior can definitely change the simulation value. In addition, process of drilling, soldering and launcher placement can affect the value of measurement. Furthermore, as the measurement take place in the open environment, the radiation from the antenna will radiate in free space causing high attenuation and decrease signal strength.

4. Conclusion

The combination of log periodic antenna together with two bandpass filters was a new approach. Results from measurement agree well to the simulation. However slightly shifted may be due to manual fabrication process.

References

[1] S. C. Gao, L. W. Li, T.S. Yeo, M.S. Leong, “A dual-frequency compact microstrip patch antenna”, vol. 36, No. 6, pp. 1669-1682, 2001.

[2] Z. Zhang, M. F. Iskander, Z. Yun, A. Host-Madsen, “Hybrid Smart Antenna System Using Directional Elements”, IEEE Transaction on antenna and propagation, Vol. 51, No. 10, 2003.

[3] M. K. A. Rahim, P. Gardener, “The design of nine element quasi microstrip log periodic antenna”, Proc. Conference RF and Microwave, RFM 2004, pp. 136-139, Oct. 2004.

[4] M. G. Young, L. Jones, E., *Microwave Filters, Impedance-Matching Network and Coupling Structures*, Artech House, 1980.

[5] T. Edward, *Foundations for Microstrip Circuit Design*, 2-nd edition, John Wiley and Sons, 1991.

[6] L. Besser, R. Gilmore, *Practical RF Circuit Design for Modern Wireless System*, Artech House, Boston, London.

[7] Z. Awang, *Microwave Engineering for Wireless Communication*, Prentice Hall, 2006.