Pattern and Frequency Reconfigurable Meander Line Yagi-Uda Antenna

M. Utayo, W. Sangthongngam, C. Kittiyanpunya, and M. Krairiksh
Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok 10520, Thailand

***Abstract*—This paper presents a pattern and frequency reconfigurable meander line Yagi-Uda antenna for digital terrestrial television reception. To achieve a compact size for installing on a vehicle, the antenna is designed with meander line. The main beam switching and resonant frequency tuning are accomplished by loading two driven elements and four parasitic elements with the short or open of RF switches. The frequency is reconfigured with different electrical length of the driven element. The direction of the beam is shifted by alternating the short or open status of RF switches in parasitic elements.**

***Keywords*— reconfigurable antenna, pattern reconfigurable antenna, frequency reconfigurable antenna, Yagi-Uda antenna, meander line.**

I. Introduction

The digital terrestrial television [1] is aimed at providing services in rural and urban areas. The spectrum of digital terrestrial television is in the frequency range of 470-800 MHz. The television antennas have been proposed for TV signal reception at mobile and fixed terminals.

The Yagi-Uda antenna is the most popular antenna for TV reception worldwide due to its simple design and construction. It has high gain with unidirectional pattern which is not suitable for mobile application. Due to signal strength fluctuation, as mobile unit moves, the quality of service is degraded. In practice, a pattern reconfigurable antenna is one solution for this problem. Previous research attempted to develop the pattern reconfigurable antenna using a discrete element. In [2], a four-beam pattern reconfigurable Yagi-Uda antenna was comprised a pair of driven elements and four parasitic elements that can be switched by pin-diodes. For TV reception on vehicles, the antenna was mounted on the EBG structure. Nevertheless it has rather narrow bandwidth. This problem can be solved by a frequency reconfigurable antenna. With the combination of pattern and frequency reconfigurable antenna, it enables the alteration of radiation patterns and multi-frequency operation. Design using this strategy has been presented for Yagi-Uda patch array [3]. In addition, the size of antenna is the limitation for mounting on vehicles. The size reduction with meander line technique [4] is applicable.

This paper presents a pattern and frequency reconfigurable meander line Yagi-Uda antenna operating in the 470-800 MHz UHF TV band. This proposed antenna is based on the Yagi-Uda antenna, whose driven element and parasitic element are switched to change the main beam direction and frequency band. It is designed with meander line for size reduction.

II. Antenna Structure and Design

The objective of this work is to investigate a small size reconfigurable antenna. The radiation pattern and frequency must be reconfigurable to receive high field strength of UHF TV as the vehicle moves in different directions.

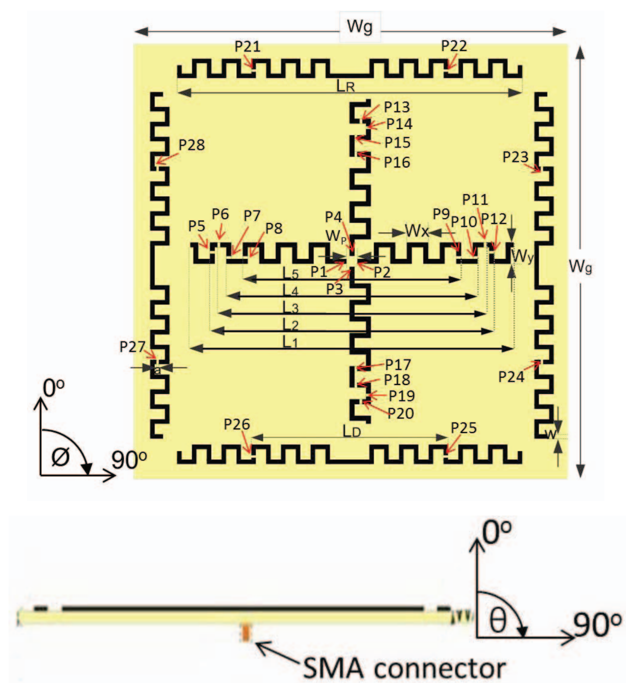


Fig. 1. Geometry of the pattern and frequency reconfigurable meander line Yagi-Uda antenna.

The antenna metallization is etched on an FR4 printed circuit board (PCB). The thickness of the substrate is h = 1.6 mm, dielectric constant is ε_r = 4.2 and the loss tangent is 0.0012. As shown is Fig. 1, the proposed antenna consists of a two driven elements and four parasitic elements. To achieve switched beam and reconfigured frequency, the metal pads are used to connect (short status) or disconnect (open status), as attached onto the element of the antenna at P_N where N = 1, 2, 3,…, 28. The main beam is switched by the driven elements and the parasitic elements act as reflectors or directors. Thus, alteration of radiation directions are based on principle of Yagi-Uda antenna.

TABLE I. THE OPTIMAL DIMENSIONS OF THE PROTOTYPE ANTENNA

Parameters	**Dimension (mm)**
Total length of substrate (W_g)	270
Length of reflector (L_R)	214
Meander-line length of driven element at 722 MHz (L_5)	57
Meander-line length of driven element at 658 MHz (L_4)	67
Meander-line length of driven element at 626 MHz (L_3)	71
Meander-line length of driven element at 594 MHz (L_2)	75.5
Meander-line length of driven element at 514 MHz (L_1)	86
Length of director (L_D)	121
Width of feed port (W_P)	6
Width of meander line structure (W_X and W_y)	12
Spacing within parasitic and driven element (a)	1.5
Width of meander line structure (W_X and W_y)	12

All structure elements are the meander line structure. For digital TV, the resonant frequency between 470-800 MHz is allocated at 514, 594, 626, 658, and 722 MHz, respectively. The frequency is reconfigured with electrical length of driven elements. The resonant frequencies are inversely correlated to electrical length. The antenna design is based on the Yagi-Uda antenna. The initial design was as shown in [5]. Usually, the electrical length of the radiating element (driven) can be determined from 0.49 wavelength at the resonant frequency. In the lower operating band, the frequency is designed to resonate at 514 MHz, the normal electrical length is equal to 292 mm. For the meander line, the length is 178 mm. The other resonant frequencies are shown in Table. I. The shifted frequency is achieved with short/open of metal pads on driven elements to define electrical length. A meander line length of the reflector is fixed at 214 mm, the separation between the driven element and the director are 122.6 mm to obtain the smallest possible

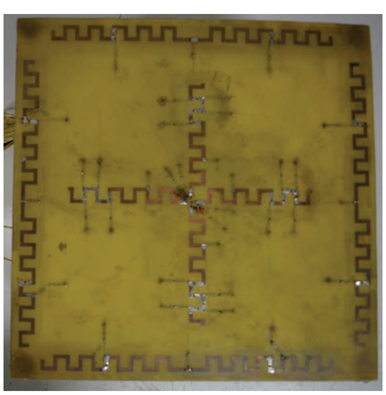
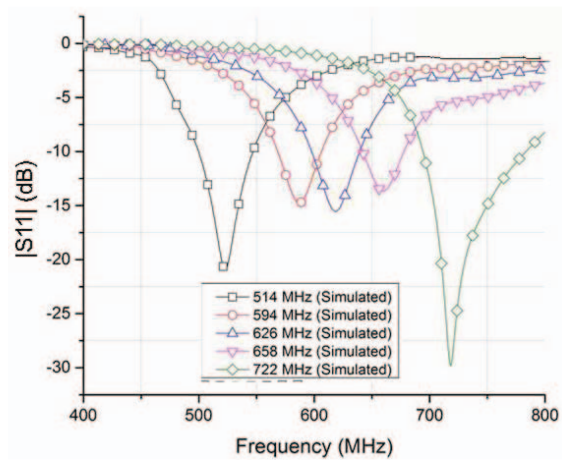


Fig. 2. Photograph of the fabricated antenna.

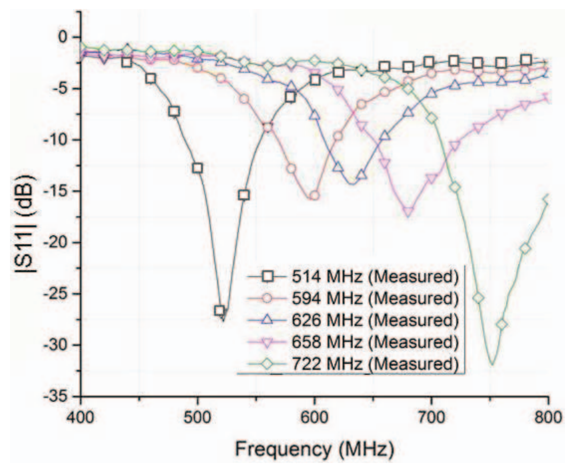
dimensions, and the length of director is varied to obtain the highest directivity. The final design for antenna operation is summarized in Table I.

III. RESULTS

In order to demonstrate the reconfigurable Yagi-Uda antenna developed in this work, an ideal switch models are used to imitate the RF switches for proof of concept, i.e., the On or Off states of the RF switches are simulated with the presence or absence of a metal pad with an area of 0.5x1.5 mm^2. The real RF switch (pin diode) will be investigated in the future work.



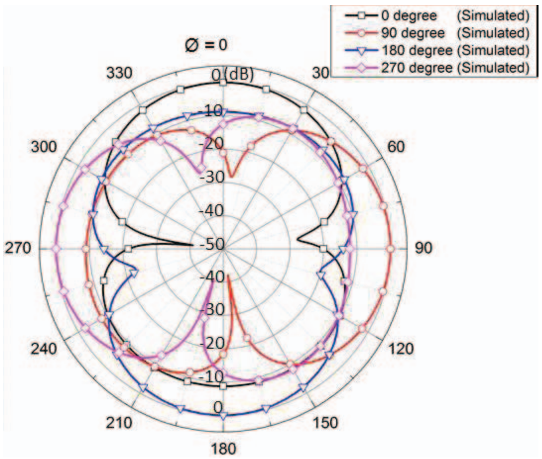
(a)



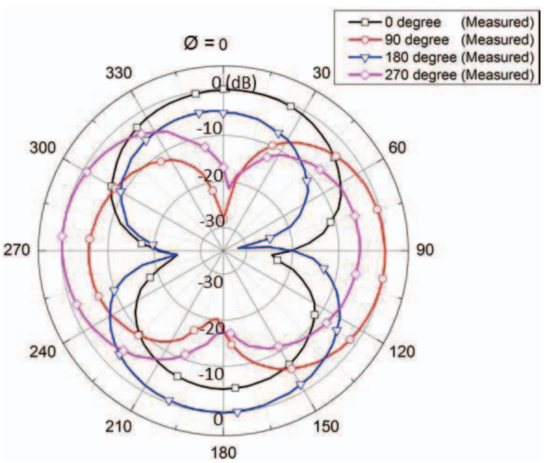
(b)

Fig. 3. The reflection coefficients for each center frequency (Result of radiation direction at 0^o) ; (a) Simulated results (b) Measured results.

The antenna was fabricated according to Table I and the photograph is shown in Fig. 2. In Fig. 3, the simulated (Fig.3(a)) and measured (Fig.3(b)) antenna reflection coefficients are compared over the tuning sub-bands for main beam direction at 0^o. The simulated impedance bandwidth ($|S11| \leq -10$ dB) for resonant frequency at 514, 594, 626, 658, and 722 MHz are 11.7%, 7.0%, 7.0%, 6.8%, and 13.0%, respectively. The measured results of impedance bandwidth



(a)



(b)

Fig. 4. The E-plane radiation patterns at 514 MHz; (a) Simulated results (b) Measured results.

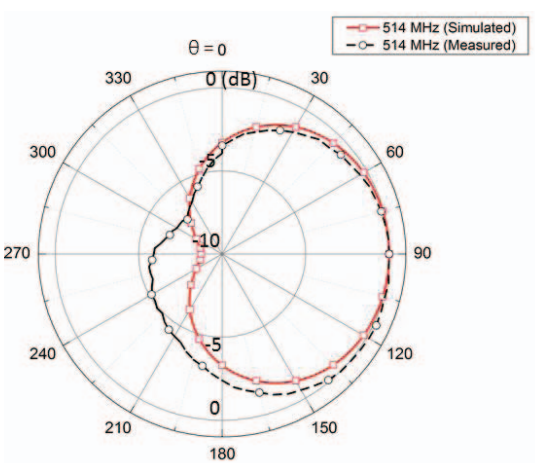


Fig. 5. The simulated and measured H-plane radiation patterns at 514 MHz

($|S11| \leq$ -10 dB) for the resonant frequency at 514, 594, 626, 658, and 722 MHz are 12.5%, 8.0%, 8.0%, 11.4%, and 14.8%, respectively. It is noted that reasonably good agreement between the simulated and measured results are obtained. In other radiation directions, similar impedance bandwidth results are obtained.

The orientation of rectangular coordinate system for all radiation pattern is identical to Fig. 1. Fig. 4(a) illustrates the simulated E-plane radiation patterns for the four directions at 514 MHz. The simulated maxima of the main beam are at 0^o, 90^o, 180^o, and 270^o. The simulated gains are 4.29 dBi, 4.31 dBi, 4.48 dBi, 4.80 dBi and 4.51 dBi at 514, 594, 626, 658 and 722 MHz, respectively.

The radiation patterns of the prototype antenna were measured and compared with simulated results. Fig. 4(b) shows measured radiation patterns at 514 MHz for four different directions. The measured E-plane results in Fig. 4(b) agree reasonably well with the simulated E-plane results in Fig. 4(a). The measured maxima of the main beams are at 5^o, 93^o, 181^o, and 275^o. The measured gains for the corresponding frequencies are 3.7 dBi, 2.9 dBi, 3.7 dBi, 3.8 dBi and 3.7 dBi, respectively. The disparities between the measured and simulated gain are attributable to the measured beam steering angles are larger than that of the simulated one and the fabrication error. Fig. 5 illustrates the simulated and measured H-plane patterns indicating that all main beams are in direction of 90^o. In addition, the results of the remaining four resonant frequencies are similar to the desired patterns.

IV. CONCLUSION

In this paper, the pattern and frequency reconfigurable meander line Yagi antenna is proposed for the UHF TV band. The design for multiple parasitic and driven elements loaded with short/open status was realized which allows a main beam switching and resonant frequency tuning. In addition, the bandwidth of each tuning resonant frequency is moderately wide. The radiation pattern is able to cover the full azimuth plane. Moreover, the size of proposed antenna can be reduced with the meander line technique. Thus, the proposed antenna can operate at desired frequencies and has high potential for TV reception on vehicles.

REFERENCES

[1] Recommendation ITU-R BT.1368-12, "Planning Criteria, Including Protection Ratios, for Digital Terrestrial Television Services in the VHF/UHF Bands," *BT series Broadcasting service (television),* 2015.

[2] C. Kittiyanpunya and M. Krairiksh, "A Four-Beam Pattern Reconfigurable Yagi-Uda Antenna," *IEEE Trans. Antennas Propag.,* vol. 61, no. 12, pp. 6210-6214, Dec. 2013.

[3] H. A. Majid, M. K. A. Rahim, M. R. Hamid and M.F. Ismail, "Frequency and Pattern Reconfigurable Yagi Antenna," *J. of Electromagn. Waves and Appl.,* vol. 26, pp. 379–389, 2012.

[4] V. B. Ambhore and A. P. Dhande, "An Overview on Properties, Parameter Consideration and Design of Meandering Antenna," IJSSAN., vol. 1, pp.59-62, 2012.

[5] C. A. Balanis, *Antenna Theory: Analysis and Design,* 3rd ed. John Wiley, 2005.