

IMPROVEMENTS IN IMPEDANCE BANDWIDTH OF MICROSTRIP PLANAR DIPOLE ANTENNAS FOR DIGITAL TELEVISION SIGNAL RECEPTION USING SLOT TECHNIQUES

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Abstract

This research investigated the enhancement of impedance bandwidth in a planar circuit microstrip dipole-type antenna for digital television (DTV) applications. A printed microstrip dipole-type antenna was designed with a center frequency of 650 MHz, and the slot technique was used to increase the bandwidth. The position and number of slots effectively controlled the impedance bandwidth of the antenna. A bandwidth of 453 MHz was achieved using 7 slots. This approach benefited from a broader, well-matched impedance bandwidth. After applying slots to the planar dipole, the antenna achieved a bandwidth of 63.65%, ranging from 452 to 905 MHz. This covered the DTV application range and also expanded the gain to 1.13 dBi at the center frequency, with gain ranging from 2.28 dBi to 3.41 dBi compared with a conventional planar dipole antenna. The radiation efficiency was consistently greater than 65% across the frequency band of the antenna. The measured results demonstrated good agreement with the simulated figures, validating the broadband performance for application reception in the DTV range.

Keywords: Bandwidth; Digital Television Application; Dipole-Type Antenna; Enhancement of Impedance; Microstrip; Slot Technique

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Introduction

Thailand established a ground-based digital television (DTV) broadcasting system in 2024 to replace traditional analog television broadcasts. DTV delivers high-resolution high-definition television (HDTV) and ultra-high-definition television (UHDTV) signals, providing superior digital video quality with vivid colors, sharpness, an extra-wide-screen observed format, and Dolby Digital high-quality surround sound. HDTV and UHDTV technologies have now become a crucial aspect of DTV broadcasting. The receiving antennas must be designed with higher gain, omnidirectional capabilities, and a wide bandwidth to cover the entire frequency range of DTV operational bands (Tsai and Chen, 2010; Chen and Tsai, 2011; Li *et al.*, 2014). This article presents printed microstrip dipole antennas, focusing on designs that work well across a wide range of frequencies in the DTV application band. The characteristic impedance of most dipole antennas depends on the dimensions of the ground plane. An appropriately sized ground plane is required for effective impedance matching within the performance band (Chi *et al.*, 2007; Chen *et al.*, 2008; Bhujbal *et al.*, 2014; Pratumsiri and Janpugdee, 2017). A dipole is a narrowband antenna; therefore, it is crucial to design the antenna to cover a broader frequency range. The planar dipole presents an intriguing alternative for DTV applications. This paper examines the improvements in impedance bandwidth of a planar microstrip dipole antenna for DTV applications. The impedance bandwidth is adjusted using the slot technique following Duangtang and Wongsan (2019). Simulations are conducted using software to compare with the measured results. The structure is then designed and adjusted (Chen, 2008; Kim *et al.*, 2018; Desai *et al.*, 2020; Teimouri *et al.*, 2022;), considering various slot dimensions, the number of slots, the symmetry of the reflection coefficient, and the magnitude of S_{11} (Foo, 2020; Deng *et al.*, 2020; Shariatzadeh *et al.*, 2021). Computer Simulation Technology (CST) software is used to study and design the suggested antenna model (Zhang *et al.*, 2014; Liu *et al.*, 2015; Kaushal and Shanmuganantham, 2018; Woszczyk *et al.*, 2019; Kamal *et al.*, 2022; George *et al.*, 2023; Paul *et al.*, 2023; Sadasivam and Bai, 2024; Zeain *et al.*, 2024; Al-Najjar and Sayidmarie, 2024; Petroustos *et al.*, 2025), giving a wider and better-matched impedance bandwidth covering the DTV band from 470 to 862 MHz, with an antenna gain of 3.41 dBi at 650 MHz.

Antenna

Planar microstrip dipole antenna configuration

A microstrip dipole antenna design at a center frequency of 650 MHz is shown in Figure 1. This dipole was printed as a rectangular line on an FR4 dielectric substrate with size 250 mm × 45 mm and thickness 1.60 mm and relative permittivity $\epsilon_r = 4.40$. The loss tangent for FR4 operating frequency was $\tan\delta = 0.020$ to adjust the center frequency in the DTV application. A frequency range of 470 MHz to 862 MHz was selected as the prototype of a traditional microstrip dipole antenna. The dimensions were $W_1 = 250$ mm, $W_2 = 124$ mm, $W_3 = 124$ mm, $L_1 = 45$ mm, $g_1 = 2$ mm, $H_1 = 1.6$ mm, and $H_2 = 0.035$ mm. The bandwidth and magnitude of S_{11} , or S_{11} (at -10 dB), covering 550 to 807 MHz, did not support the application to DTV, as shown in Figure 2. The feed line from the bottom of the antenna was designed to match the antenna with the SMA. The coaxial probe feed technique is commonly recommended for feeding a microstrip patch antenna. The higher surface of the microstrip patch is soldered to the inner conductor of the coaxial probe feeder with the 50 Ω SMA (SubMiniature version A) RF (Radio-Frequency) of the transmission line connector in the bottom microstrip dipole antenna (simulated as waveguide port in CST) to provide excellent impedance matching. A planar dipole radiator gives a wider frequency response than a cylindrical or wire equal to both the current distribution and the inner impedance (Butter, 1982). A wire dipole assumes a constant cross-sectional radius; therefore, the concept of an equivalent radius can be applied to non-cylindrical conductors. This approach can be used to estimate the characteristics of thin wires and the linear dispersion properties of conductors with arbitrary cross sections by replacing a non-circular boundary with a circular one that has an equivalent radius. In this work, the radius of a cylindrical dipole was converted to the width of a planar dipole using Equation (1) following the method described by Butter (1982).

$$a_{eq} = \frac{2w}{4} = \frac{\text{Strip width}}{4} \quad (1)$$

Where a_{eq} is the equivalent radius.

The wavelength for designing the rectangular patch antenna center operating frequency f can be empirically predicted by equations (2)-(4) (Athina *et al.*, 2022; Khabba *et al.*, 2022).

$$W = \left[\frac{1}{2 \times f_r v(\mu_0 \epsilon_0)} \right] v(2/(\epsilon_r + 1)) \quad (2)$$

$$W = \left[\frac{v_0}{2 \times f_r} \right] v(2/(\epsilon_r + 1))$$

$$\lambda = \frac{\lambda_0}{\sqrt{\epsilon_{\text{eff}}}} \quad (3)$$

$$f = \frac{c}{a \sqrt{\epsilon_{\text{eff}}} \times \frac{L}{2}} \quad (4)$$

The effective dielectric constant of the patch can be determined using equation (5) (Athina *et al.*, 2022).

$$\epsilon_{\text{eff}} \gg \frac{1}{2}(\epsilon_r + 1) + \left(\left(\frac{\epsilon_r - 1}{2} \right) \left[1 + 12 \left(\frac{h}{w} \right) \right]^{\left(\frac{1}{2} \right)} \right) \quad (5)$$

while the increasing longitudinal extension of the patch ΔL can be found from equation (6) (D. Athina *et al.*, 2022).

$$\left(\frac{\Delta L}{h} \right) = (0.4123) \times \left\{ \left[\frac{(\epsilon_{\text{reff}} + 0.301) \times \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{\text{reff}} - 0.258) \times \left(\frac{w}{h} + 0.8012 \right)} \right] \right\} \quad (6)$$

The initial antenna length is determined using equation (7)

$$L = \frac{\lambda}{2} \quad (7)$$

with the effective length given by equation (8)

$$L_{\text{eff}} = L + 2\Delta L \quad (8)$$

The length of the slot in the rectangular patch can be determined by equation (9) (Athina *et al.*, 2022).

$$\text{length of slot} = \left[\frac{1}{2f_r \sqrt{\epsilon_{\text{reff}}} \sqrt{\mu_0 \epsilon_0}} \right] - 2\Delta L \quad (9)$$

The width of the slot can be determined theoretically using equation (10) (Athina *et al.*, 2022).

$$\text{width of slot} = \left(\frac{c_0}{2f_{\text{lower}} \sqrt{\epsilon_{\text{reff}}}} \right) - 2 \left(L + 2\Delta L - \frac{\lambda}{60} \right) \quad (10)$$

where;

c_0 refers to electromagnetic waves that propagate in free space or a vacuum at the speed of light.

f is the center frequency

ϵ_{eff} is the effective dielectric constant

L is the length of an antenna

f_{lower} is the lower bound frequency

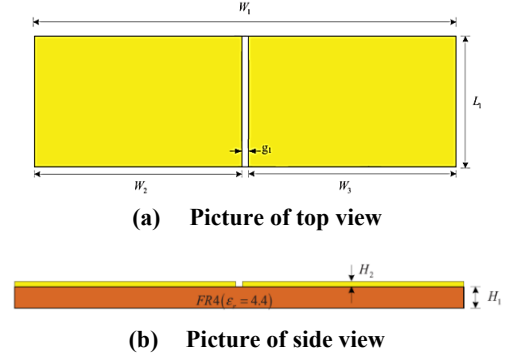


Figure 1. A traditional print microstrip dipole antenna

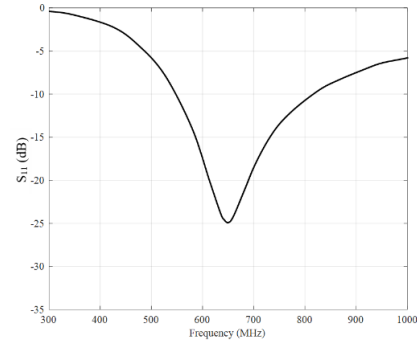


Figure 2. Simulation results of the magnitude of S_{11} for the basic print microstrip dipole antenna

Simulation analysis, results and antenna discussions

CST simulation software with time-domain solvers of the designed antennas was used to compare with the measured results and adjust and design various slot dimensions to increase the bandwidth of a planar microstrip dipole antenna. The antenna design described in included 4 slots on the upper view of a printed microstrip dipole antenna. The slot span s was equal to 1 mm, and the distance between slots d was 2 mm. The length of each slot increased by 0.003 wavelengths, as shown in Figure 3(a). The bandwidth

of the antenna was extended with improved matching, while the midpoint operating frequency response shifted from 650 MHz to 560 MHz, as indicated in Figure 4. The adoption of slot techniques as a method to enhance antenna performance in terms of bandwidth, gain, and radiation pattern is widely accepted. The simulation results demonstrated that the optimized design improved the gain of both major beams by more than 3 dBi compared to the original gain. If the leader is flawless, the polarization of the electric waveform will successfully increase.

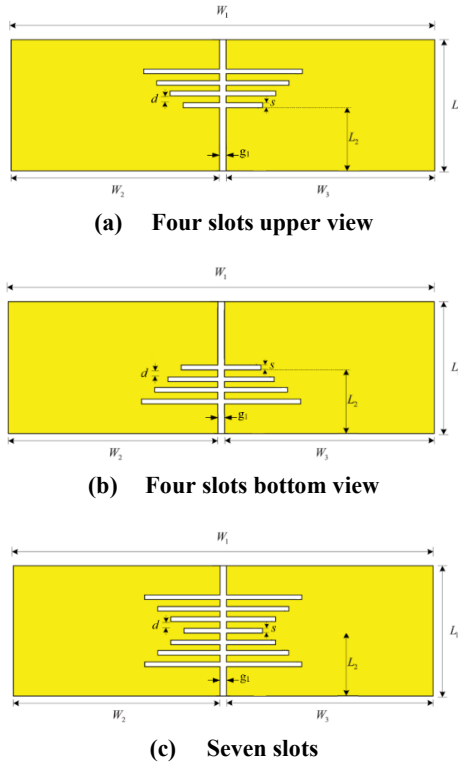


Figure 3. Planar microstrip dipole antennas with various slots

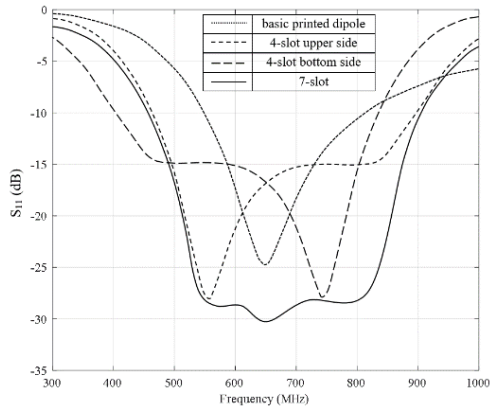


Figure 4. Simulated results of the magnitude of S_{11} for various slot positions on the planar microstrip dipole antenna

The effect of the slot positions was analyzed to design the parameters of slots on the planar antenna. Figure 3(b) and (c) illustrate the 4-slot and 7-slot configurations for the printed microstrip dipole antenna, respectively. The antenna with a 4-slot configuration in the bottom view exhibited extended bandwidth with good impedance matching; however, the frequency response shifted from 650 MHz to 745 MHz. This behavior contrasted with the 4-slot configuration in the upper view. Conversely, the 7-slot configuration demonstrated an extended bandwidth with better impedance matching but the resonance frequency did not pass through as expected. Therefore, this characteristic indicated that controlling the frequency response of a printed microstrip dipole antenna can be effectively managed, and a 7-slot configuration was adequate. We then investigated the impact of the number of slots on the antenna. Figure 5 illustrates the printed

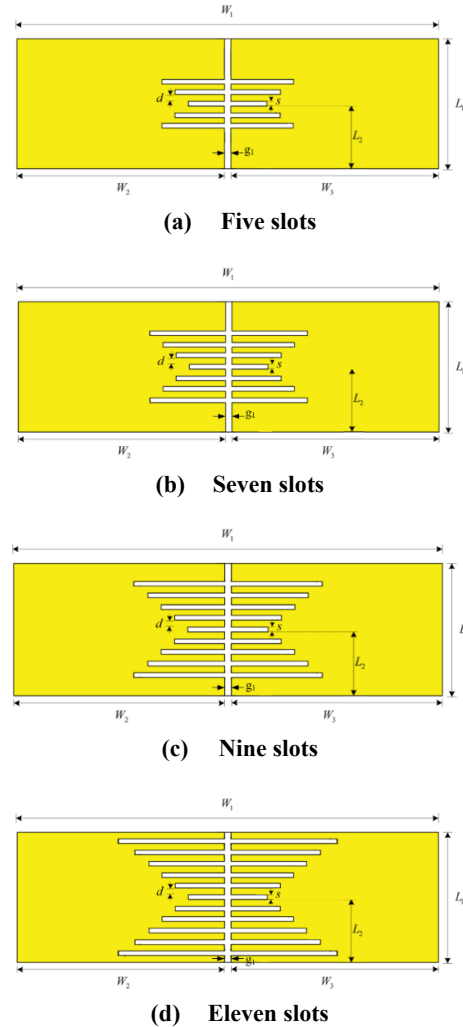


Figure 5. Print microstrip planar dipole antennas with various slots

microstrip dipole antenna with 5, 7, 9, and 11 slots. Figure 6 demonstrates that the resonant center frequency consistently remained at 650 MHz, independent of the number of slots, whereas the impedance bandwidth exhibited variation corresponding to the number of slots. A broader bandwidth with improved impedance matching was achieved as the number of slots increased. When the number of slots exceeded seven, a reduction in antenna gain was noted despite the continued improvement in bandwidth. The 7-slot configuration provided sufficient bandwidth to support DTV applications, as indicated by the data in Table 1. The optimal slot parameter was a symmetrical 7-slot configuration on the planar antenna. Figures 7 and 8 compare the gains and radiation patterns of a basic printed microstrip dipole antenna with our proposed printed dipole

antenna with 7 symmetrical slots at lower frequencies (510 MHz), center frequency (650 MHz), and higher frequencies (790 MHz). Our proposed design exhibited enhanced impedance bandwidth and gain, with a wider operational bandwidth and excellent impedance matching. The antenna was well-suited for modulating frequencies relevant to DTV applications and provided an impedance bandwidth with a 2.5:1 voltage standing wave ratio, favorable for DTV signal reception.

The next step demonstrated the design using the CST software suite. A prototype was fabricated to compare the simulated S_{11} results. The gain of the antenna printed dipole is shown in Figures 9-12. The test results concurred with the simulation results using the CST software. However, the initial antenna design did not meet the resonant frequency requirements across the entire operating bandwidth

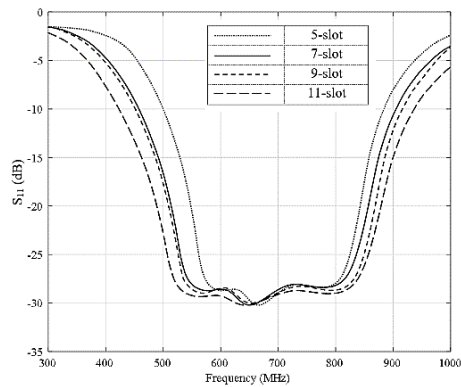


Figure 6. Simulated results of the magnitude of S_{11} for various numbers of slot antenna

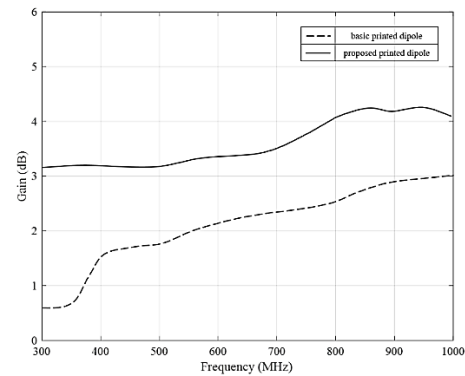


Figure 7. Simulated results of the gain of a planar dipole antenna with 7 slots

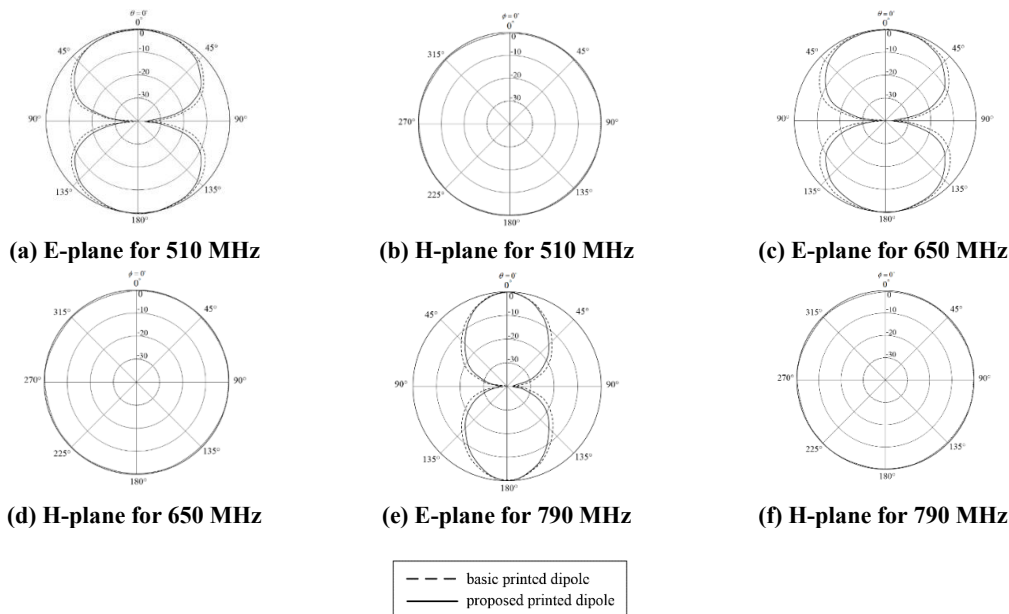


Figure 8. Simulated results of radiation patterns of a printed microstrip dipole antenna with 7 slots

of 470 to 862 MHz as specified. The gain was also relatively low and the resonant frequency response was asymmetrical. Therefore, a redesign was performed using CST software, and the simulated S_{11} results were compared using 4 slots on the upper side, 4 slots on the bottom side, 7 slots (proposed printed microstrip dipole), 5 slots, 9 slots, and 11 slots, as presented in Figures 13-30. Based on the

resonant frequency response across the operating bandwidth of 470 to 862 MHz, the 7-slot configuration provided the best performance in terms of resonant frequency response across the operating bandwidth. This design also demonstrated improved impedance matching and higher gain compared to the other configurations, resulting in enhanced overall antenna performance.

Table 1. Simulated results

Planar microstrip dipole antenna	Frequency range (MHz)	Bandwidth (MHz)	Gain at center frequency (dBi)
Traditional planar microstrip dipole	550.10 - 807.14	257.13	2.281
Four slots in upper side	465.27 - 900.21	435.10	2.752
Four slots in bottom side	400.36- 840.23	440.20	2.831
Five slots	500.21 - 880.10	380.30	3.321
Seven slots (Proposed printed microstrip dipole)	452.20 - 905.30	453.52	3.412
Nine slots	450.10 - 920.42	470.32	3.403
Eleven slots	425.34 - 935.13	510.12	3.384

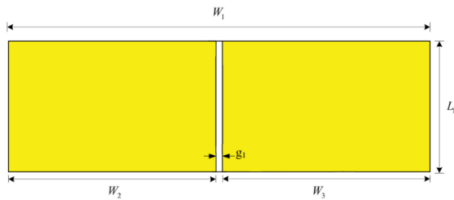


Figure 9. Traditional printed dipole antenna



Figure 10. The prototype for the printed microstrip dipole antenna

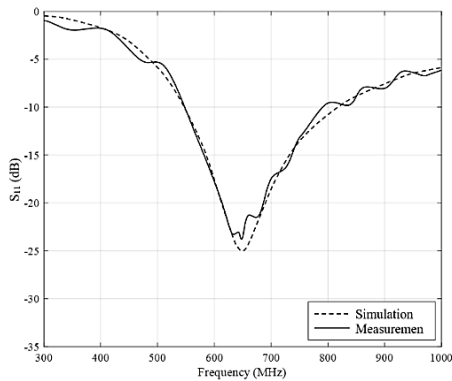


Figure 11. Simulated and measured results of the magnitude of S_{11} for the basic printed microstrip dipole antenna

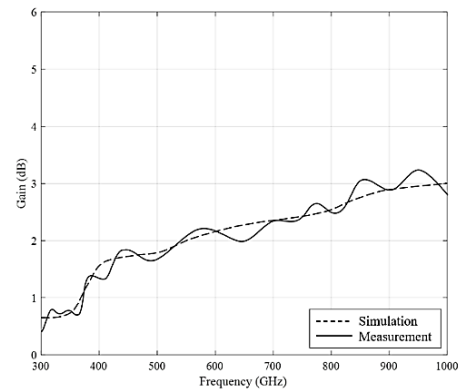


Figure 12. Simulated and measured results of the gain of the basic printed microstrip dipole antenna

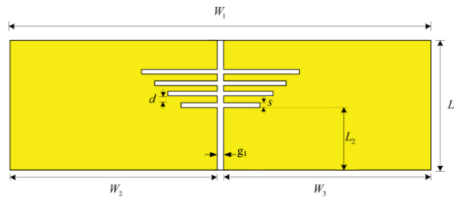


Figure 13. Four slots in the upper side of the antenna



Figure 14. The prototype with 4 slots in the upper side of the dipole antenna

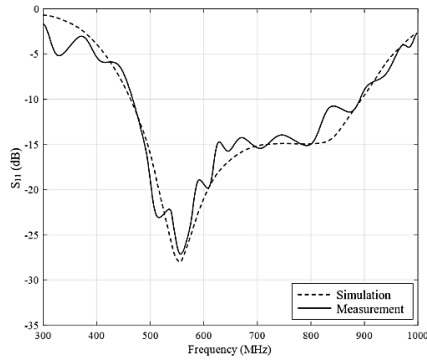


Figure 15. Simulated and measured results of the magnitude of S_{11} with 4 slots in the upper side of the antenna

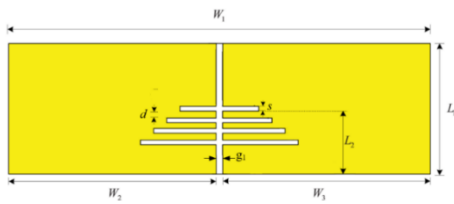


Figure 16. Four slots in the bottom side of the antenna



Figure 17. The prototype with 4 slots in the bottom side dipole antenna

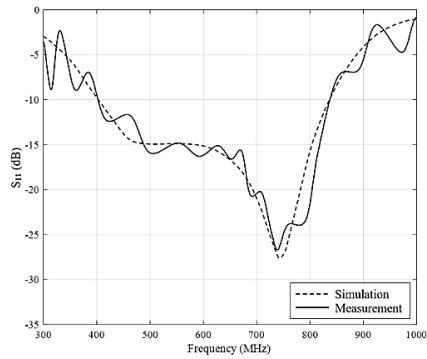


Figure 18. Simulated and measured results of the magnitude of S_{11} with 4 slots in the bottom side of the antenna

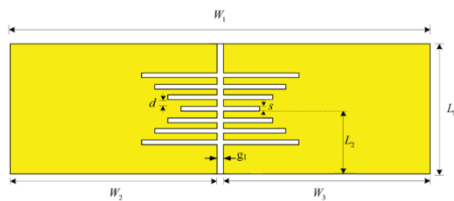


Figure 19. Seven slots (Proposed printed microstrip dipole)

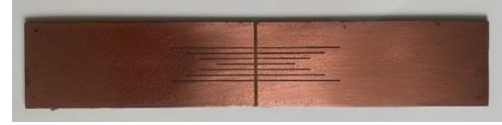


Figure 20. The prototype with 7 slots (Proposed printed microstrip dipole antenna)

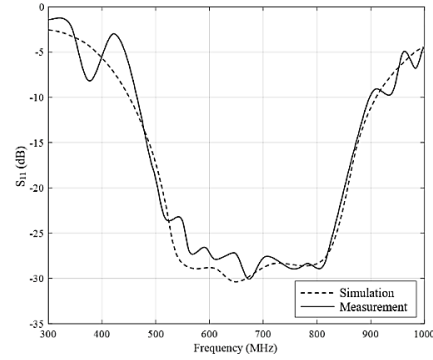


Figure 21. Simulated and measured magnitude of S_{11} with 7 slots for the proposed printed microstrip dipole antenna

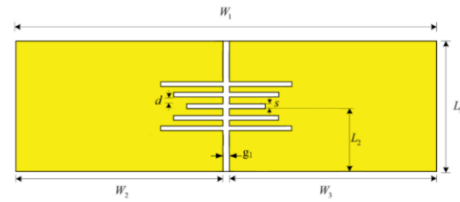


Figure 22. Five slots



Figure 23. The prototype planar dipole antenna with 5 slots

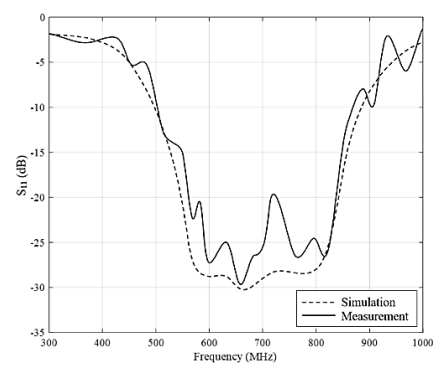


Figure 24. Simulated and measured results of S_{11} with 5 slots in the antenna

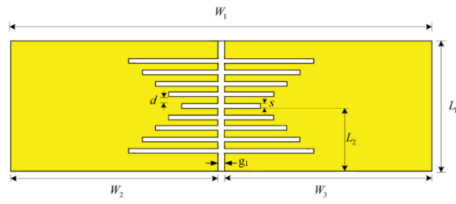


Figure 25. Nine slots



Figure 26. The prototype planar dipole antenna with 9 slots

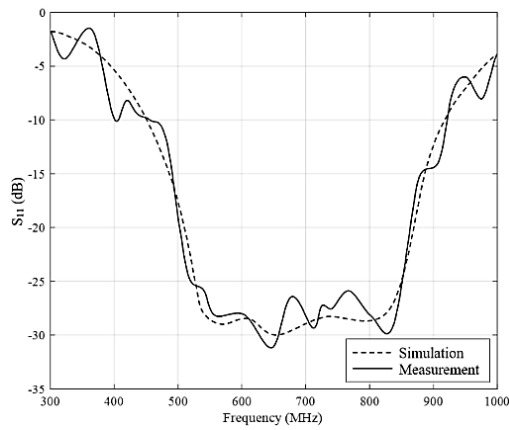
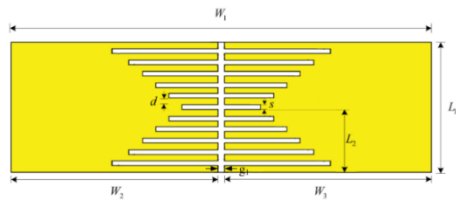
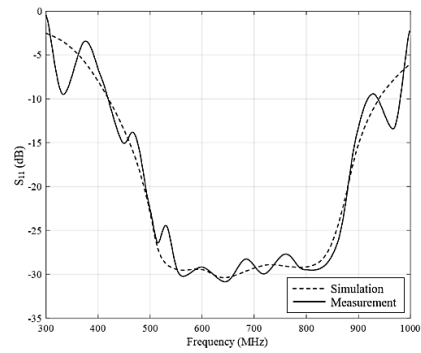
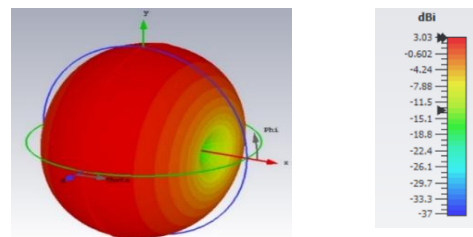
Figure 27. Simulated and measured results of the magnitude of S_{11} with 9 slots in the antenna

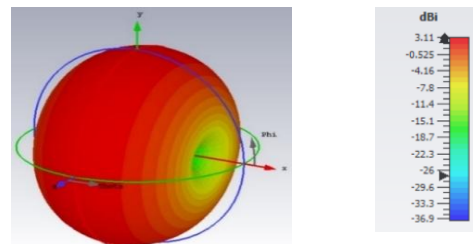
Figure 28. Eleven slots



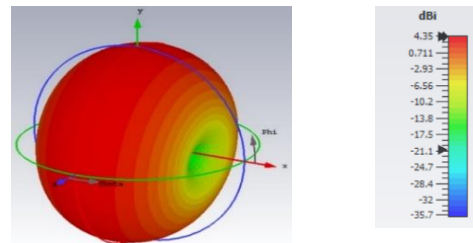
Figure 29. The prototype planar dipole antenna with 11 slots

Figure 30. Simulated and measured results of the magnitude of S_{11} with 11 slots in the antenna

(a) 510 MHz



(b) 650 MHz



(c) 790 MHz

Figure 31. Simulation of 3D radiation for the band-notched printed dipole antenna at frequencies of (a) 510 MHz, (b) 650 MHz, and (c) 790 MHz

The antenna gain varied from 2.28 to 3.41 dBi, with an increase of 1.13 dBi at the center frequency. Throughout its operational bandwidth, the antenna demonstrated radiation efficiency consistently greater than 60%. Additional details on radiation patterns and other radiation characteristics of the antenna are discussed in the presentation. Figure 31 illustrates the three-dimensional (3D) normalized radiation patterns of the band-notched printed dipole antenna at three distinct frequencies. The results indicated that the antenna consistently maintained stable radiation pattern shapes in both the E- and H-

planes across the examined frequencies. This stability highlighted a significant advantage of the proposed antenna design.

To validate the proposed antenna design, surface current distributions at three representative frequencies-510 MHz, 650 MHz, and 790 MHz-were simulated using CST Microwave Studio, as shown in Figure 32. The measured gains were compared with the simulated results, as illustrated in Figure 33. Figure 34 compares the simulated and measured cross-polarization and co-polarization power levels.

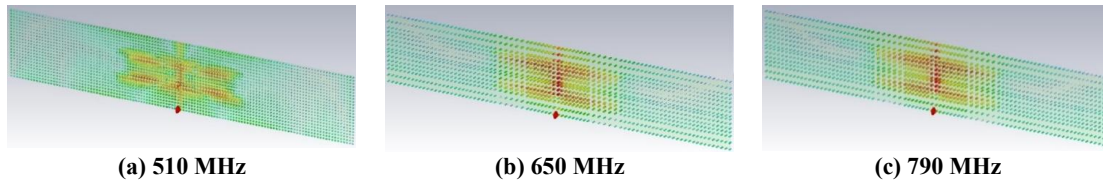


Figure 32. Simulated surface current of the band-notched printed dipole antenna at frequencies of (a) 510 MHz, (b) 650 MHz, and (c) 790 MHz.



Figure 33. Simulated and measured results of the gain for the 7-slot proposed printed microstrip dipole antenna. (a) Hardware setup to measure the gain, and (b) Gain of the printed dipole antenna.

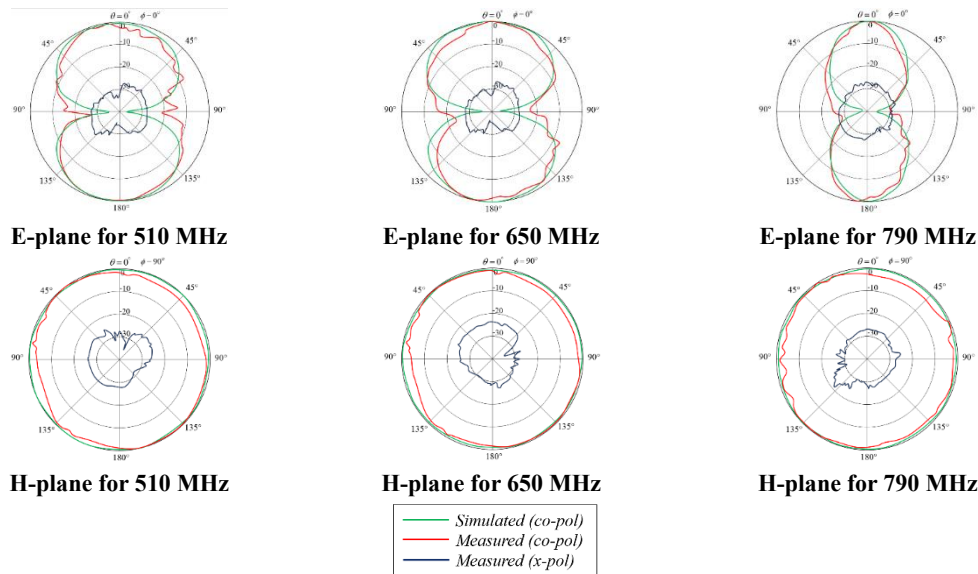


Figure 34. Comparison of the simulated and measured cross-polarization and co-polarization of the printed microstrip dipole antenna at lower, center, and higher operating frequencies

Figure 35 compares the simulated and measured radiation efficiency of the proposed antenna across its operating band. The results demonstrated that the radiation efficiency remained consistently above 65% throughout the entire frequency range. Table 2 provides a comparative analysis of the simulated and measured results for all basic printed microstrip dipole antennas, including our proposed design.

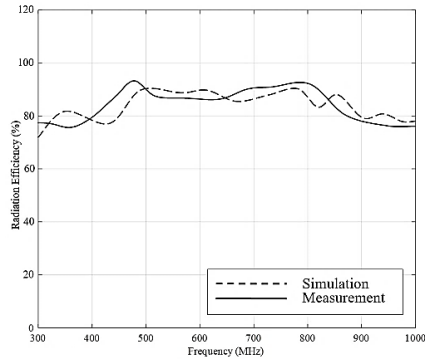


Figure 35. Simulated and measured efficiency across the operating band of the proposed antenna.

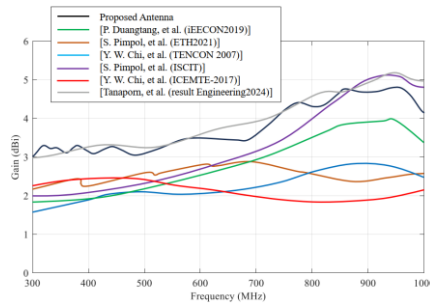
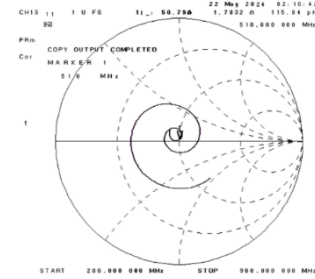


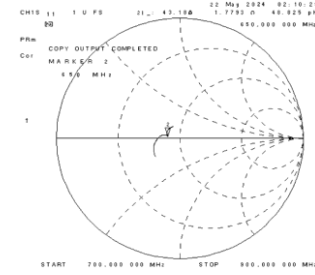
Figure 36. Comparison with recently published similar studies.

Figure 36 shows that our proposed antenna outperformed previously reported wideband UHF antenna designs for DTV reception, especially when evaluated against antennas of similar or comparable

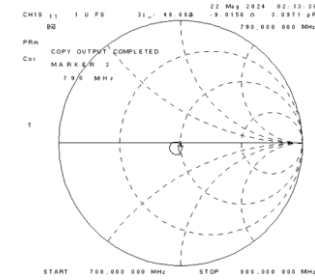
size (Chen and Tsai, 2011; Pimpol and Wongsan, 2013, 2021; Chi and Wong, 2007a, 2007b; Payommai *et al.*, 2025).



(a) 510 MHz



(b) 650 MHz



(c) 790 MHz

Figure 37. Measured input impedance of the printed dipole antenna at frequencies of (a) 510 MHz, (b) 650 MHz, and (c) 790 MHz.

The measured input impedance of the PCB-printed dipole antenna across the operating frequency range of 463.26 MHz to 915.62 MHz was

Table 2. The simulated and measured results

Printed microstrip dipole antenna	Frequency range (MHz)		Bandwidth (MHz)		Gain at center frequency (dBi)	
	Sim.	Meas.	Sim.	Meas.	Sim.	Meas.
Basic printed microstrip dipole antenna	550.03 - 812.02	550 - 787	262.17	237.02	2.282	2.03
Four slots in upper side	465.21 - 900.62	470 - 885	435.14	415.04	2.751	2.61
Four slots in bottom side	400.23 - 840.41	400 - 840	440.22	440.21	2.832	2.72
Five slots	500.14 - 880.16	500 - 865	380.21	365.17	3.321	3.23
Seven slots (Proposed printed microstrip dipole)	452.32 - 905.10	465 - 900	453.11	435.21	3.412	3.35
Nine slots	450.15 - 920.23	455 - 922	470.32	467.19	3.401	3.29
Eleven slots	425.21 - 935.16	425 - 912	510.22	487.12	3.383	3.19

$50.79 + j1.7832 \Omega$ at 510 MHz, $43.18 + j1.7793 \Omega$ at 650 MHz, and $48.88 - j9.0156 \Omega$ at 790 MHz, as presented in Figure 37. The corresponding real and imaginary components of the input impedance are further illustrated in Figure 38. To evaluate the antenna performance in a realistic environment, the prototype 7-slot planar dipole antenna was tested indoors. The received signal parameters were measured using a field strength meter, as depicted in Figure 39. The measured signal power was 67.7 dB μ V and the carrier-to-noise ratio (C/N) was greater than 27.7 dB.

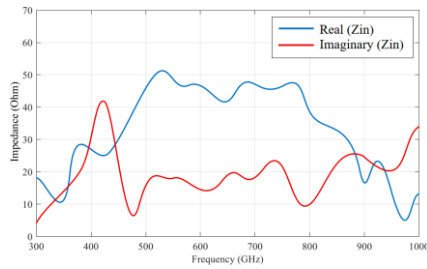


Figure 38. Input impedance (Z_{in})

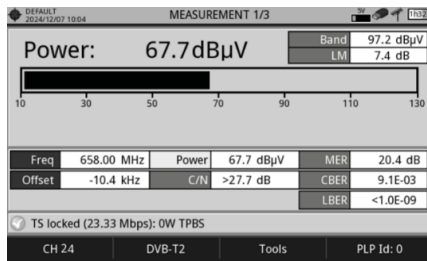


Figure 39. Measurement results of the prototype 7-slots planar dipole antenna.

After the antenna fabrication was completed, it was tested in a practical application by connecting the slotted printed circuit board (PCB) dipole antenna, as shown in Figure 40.

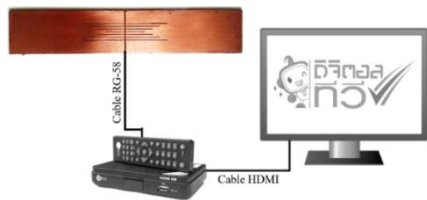


Figure 40. Connection of the DTV antenna to the television

Thailand currently broadcasts 26 DTV channels, as listed in Table 3. The signal reception test was conducted using the proposed antenna to receive DTV signals. The testing was carried out at Rajamangala University of Technology Isan. The test site was 14 kilometers from the broadcasting

station at the Thai Public Broadcasting Service (TPBS) transmission site, located at 272, Moo 9, Ban Nong Ped Nam, Khok Kruat Subdistrict, Mueang Nakhon Ratchasima District, Nakhon Ratchasima Province. The coordinates of the broadcasting station are 14.94769° N, 101.99505° E, with a transmission antenna height of 156 meters. The coordinates of the test site at Rajamangala University of Technology Isan are 14.9875° N, 102.1180° E. The effective radiated power (ERP) of the transmission station is 50 kW, and the bearing from the test site to the broadcasting station is 251 degrees relative to true north. Figures 41 and 42 show the installation setup for the signal reception tests. The urban area used for testing had significant signal reception issues due to the presence of numerous high-rise buildings in close proximity, making signal reception problematic compared to suburban areas. The developed antenna received all the DTV channels and achieved higher signal levels compared to commercially available antennas. The antenna was connected to a DTV receiver, and the received signal quality levels were recorded. These quality levels were then compared with four types of commercially available antennas, as shown in Figure 43. Each antenna was connected to a DTV receiver, and the signal strength was measured for each channel to evaluate and compare the reception performance. A total of 25 measurements were conducted for each antenna type, and the average signal strength values were calculated to compare their signal reception performances.

Table 3. DTV channels broadcasting in Thailand

Channel	Service Station Name
1	Channel CH5 (HD)
2	Channel NBT (HD)
3	Channel Thai PBS (HD)
10	Channel TPTV
13	Channel 3 Family
14	Channel MCOT Kids and Family
16	Channel TNN24
18	Channel NEW TV
19	Channel Spring News
20	Channel Bright TV
21	Channel Voice TV
22	Channel Nation TV
23	Channel Workpoint Creative TV
24	Channel True4U
25	Channel GMM 25
26	Channel NOW
27	Channel CH8
28	Channel 3 SD
29	Channel MONO 29
30	Channel MCOT HD
31	Channel ONE
32	Channel Thairath TV
33	Channel 3 HD
34	Channel Amarin TV HD
35	Channel BBTv CH7
36	Channel True4U

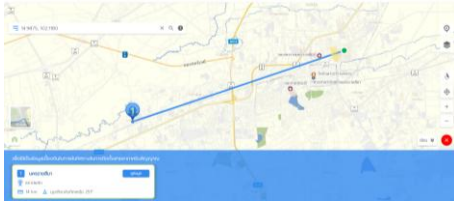


Figure 41. Measurement of the distance from the test point to the transmission station



Figure 42. Installation setup test



Type A Antenna



Type B Antenna



Type C Antenna



Type D Antenna

Figure 43. Commercially available antennas were evaluated to compare their signal reception performance.

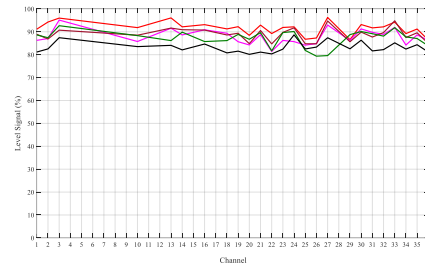


Figure 44. Comparison of received signal quality

Based on 25 repeated tests, the average received signal level of our proposed antenna demonstrated better signal reception performance than the reference antenna used for measurement and performance evaluation, as shown in Figure 44. The DTV signal levels are presented in Table 4. Our proposed antenna achieved an average received signal level of 91%, with a standard deviation of 0.6 from 25 DTV measurements.

Conclusions

This study successfully employed a slot technique to enhance the impedance bandwidth of a planar dipole antenna designed for DTV applications. The proposed antenna had a simple, low-cost, planar structure that was easy to fabricate. This technique improved the impedance matching and wideband performance and also enhanced the antenna gain, achieving 1.13 dBi at the center frequency. Our proposed printed microstrip dipole antenna had a bandwidth of 453 MHz, ranging from 463.26 MHz to 915.26 MHz. The antenna achieved a bandwidth of 63.65%, suitable for DTV applications, with a gain of 3.41 dBi using the 7 slots format. The radiation efficiency exceeded 65% over the entire operating bandwidth and satisfied the criteria

Table 4. Comparison of the received signal strength performance between our developed antenna and existing commercial antennas

Channel	Service Station Name	Signal Strength Level (%)				
		The developed prototype antenna.	Type A Antenna	Type B Antenna	Type C Antenna	Type D Antenna
1	Channel CH5 (HD)	91.14	86.25	88.9	88.62	81.15
2	Channel NBT (HD)	94.25	87.05	86.85	87.41	82.52
3	Channel Thai PBS (HD)	95.97	95.1	90.7	92.65	87.41
10	Channel TPTV	91.81	85.75	88.5	88.32	83.52
13	Channel 3 Family	96.05	91.55	91.6	86.15	84.07
14	Channel MCOT Kids and Family	92.15	88.61	90.9	89.83	82.09
16	Channel TNN24	93.11	90.85	90.75	85.72	84.65
18	Channel NEW TV	91.25	89.35	88.6	86.15	80.78
19	Channel Spring News	92.22	85.65	89.35	88.85	81.54
20	Channel Bright TV	88.43	84.24	84.8	86.72	80.14
21	Channel Voice TV	92.91	88.75	90.55	89.63	81.12
22	Channel Nation TV	89.22	81.42	84.71	81.65	80.33

for DTV applications. The potential improvement in impedance bandwidth through iterative simulations and measurements was investigated for the first time. A strong correlation was found between the simulated and measured data. This antenna is well-suited for operation in the 470 to 862 MHz frequency range and meets the target specifications.

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