A Characterization of Super Wideband Planar Antenna With Cpw Feed And Circular Shape Patch

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Abstract

Super-wideband (SWB) antenna become eagerly demanding to cover both short and long range transmission for ubiquitous services because UWB antenna are not efficient enough to diverse the communication systems. Distinctively, SWB does not have predefined range of operating frequency and need to maintain a return loss less than -10 dB and VSWR less than 2 over the entire frequency range of 10:1 bandwidth ratio whereas UWB should attain an absolute minimum bandwidth of 500 MHz or a minimum fractional bandwidth of 20%. This thesis use insertion of slot method to improve the bandwidth ratio of 1-30 GHz on the antenna system expected to achieve SWB. This thesis also use microstrip circular patch, the tapered coplanar waveguide (CPW) feed and spline curved ground plane method. This thesis gradually simulated and analyzed 4 model SWB planar antenna with tapered CPW feed, circular shape patch, and curved spline groundplane using slot in frequency range of 1-30 GHz. Simulated with FR-4 substrate with 4.3 dielectric constant, and thickness of 1.6 mm. The SWB planar antenna with tapered CPW feed, circular shape patch, and curved spline groundplane using slot have achieve total bandwidth of 96.01% (single-band) that achieve SWB bandwidth ratio of 13.91:1. The final result managed to get a SWB antenna that works in 2.1579 - 30 GHz and deeper minimum return loss at -45.5482 GHz.

Keyword— ultra wideband antenna, super wideband antenna, coplanar waveguide, ground plane, microstrip circular patch antenna, slot antenna.

I. INTRODUCTION

The pandemic that happens globally has forced many industries to use practical devices and machines by minimalizing social practices. Therefore, ultra-wideband (UWB) antenna become the interest of many industries recently. With the need of wide spectrum frequencies, it lead to the great interest of larger band antennas as a solution for a various devices. The UWB antenna is needed in many sectors, such as: cellular communication (3G, 4G, and 5G), electronic counter measure, radar, mine detection, and satellite communication.

An antenna with a bandwidth ratio equal or greater than to 10:1 is usually called a super-wideband (SWB) antenna [1]. Unlike UWB which should attain an absolute minimum bandwidth of 500 MHz or a minimum fractional bandwidth of 20%, SWB does not have predefined range of operating frequency and need to maintain a return loss less than -10 dB and VSWR less than 2 over the entire range of operating frequency on ratio of 10:1 [2]. SWB is eagerly demanding and a better solution to cover both short and long range transmission for ubiquitous services because UWB antennas are not efficient enough to diverse the communication systems [3].

This thesis uses an antenna that can achieved polarization diversity and bandwidth ratio more than 10:1 with a reflection coefficient of -10 dB named SWB antenna, which in some previous research to get the characterization have been conducted [4][5]. There are various SWB designs, such as rectangular monopole antenna with a *trapeziform* ground plane, a printed slot planar inverted cone antenna, a coplanar waveguide (CPW)-fed slot antenna, a special-shaped gap-loaded monopole antenna, and an asymmetric monopole antenna with a dual-branch feed [2][4].

This thesis simulated and analyzed the result of the improvement on tapered-CPW feed planar antenna with circular shape patch using the addition of slot with design example as shown in Figure 1. The only parameter enhanced is the bandwidth ratio. The improvement methods is expected to widen the antenna bandwidth ratio by decreasing the lower frequency so it can achieve the wider bandwidth. This thesis conduct improvement on the antenna by widening the antenna bandwidth ratio of 10:1 on 1-30 GHz with a circular shape patch, tapered-CPW feed, and spline curved ground plane using slot. The addition of the slot on the patch or groundplane can widen the bandwidth of the antenna while reducing the dimension of the antenna. The research of insertion of slot both in the patch or the groundplane already have been characterized in [2][6][7]. Combination of slot and elliptical-shaped patch already characterized in [6]. The combination of planar antenna with tapered-CPW and spline-curved ground plane already characterized in previous research [8]. This research conducted is to achieve SWB antenna that useful to cover both short range and long range and diversify communication systems which UWB antenna inefficient to cover.

II. THEORITICAL REVIEW

a. Super Wideband (SWB) Antenna

Besides ultra wideband (UWB) which is operating band from 3.1 to 10.6 GHz for wireless personal area network (WPAN) applications, the current users of WPAN are also eagerly demanding a super wideband (SWB) to cover both short range and long range transmitting for universal services [3]. SWB antenna does not have a predefined range of operating frequency. Antenna having bandwidth ratio 10:1 maintaining a return loss less than -10 dB and VSWR less than 2, over the entire range of operating frequency is considered as SWB antenna [1][2]

b. Coplanar Waveguide (CPW) Antenna

A coplanar waveguide (CPW) is a one type of strip transmission line defined as a planar transmission structure for transmitting microwave signals. CPW feed is a feed which located between the ground plane [8].

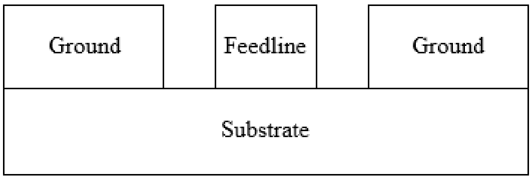


Fig. 2. Coplanar waveguide (CPW) design structure.

Figure 2 depicted that the CPW is the most frequent use as planar transmission line in RF/microwave integrated circuits. It can be regarded as two coupled slot lines. The CPW consists of three conductors with the exterior ones used as ground planes.

In designing the CPW, this thesis need some equations to define the variables, such as characteristic impedance (Z_0) and the antenna effective permittivity constant (ε_{eff}) [8]. The value used as a initial value for the antenna design. The equation is as follow:

$$Z_0 = \frac{60\pi}{\sqrt{\varepsilon_{eff}}} \frac{1}{\frac{K(k)}{K(k')} + \frac{K(kl)}{K(kl')}} \qquad (1)$$

Where Z_0 is characteristic impedance (ω) . From the equation above (1), the value of *k*, *k'*, *kl*, and *kl'* is needed to be known to get the Z_0 [9]. The equation is as follow:

$$k = \frac{a}{b} \qquad (2)$$

$$k' = \sqrt{k^2} \qquad (3)$$

$$kl = \frac{\tanh\left(\frac{\pi a}{4h}\right)}{\tanh\left(\frac{\pi b}{4h}\right)} \qquad (4)$$

$$Bf = \frac{\Delta}{fc} \qquad (5)$$

Where *a* is the antenna feedline, *b* is the antenna total feedline length, *h* is the dielectric thickness used by the antenna. The ε_{eff} value obtained by knowing the material relative permittivity (ε_r) [9]. The equation is as follow:

$$\varepsilon_{eff} = \frac{1 + \epsilon r \frac{K(k')}{K(k)} \frac{K(kl)}{K(kl')}}{1 + \frac{K(k')}{K(k)} \frac{K(kl)}{K(kl')}} \qquad (6)$$

c. Slot Antenna

A slot antenna is a radiating element which typically is formed by cutting an opening on a ground plane or patch. Usually, this opening is referred to as a slot instead of an aperture, and the length L should be much longer than the width W. For proper radiation, the length L of the slot should be around half a wavelength ($L = \lambda/2$) while the width W typically should be $W \leq (0.05 - 0.1)\lambda$ [10].

Inserting a slot on the patch of the antenna is analyzed can reduce the resonant frequency while reducing the dimensions of the antenna. With the selection of the appropriate slot can be generated dimension reduction on the antenna patch or groundplane, dual frequency and widen the band of the antenna [7].

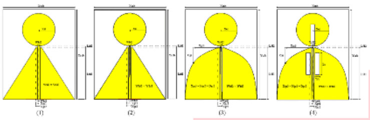
d. Parameters of SWB Antenna

There are several parameters which determine the performance of SWB antenna such as gain, radiation pattern, directivity, return loss and bandwidth. There is also bandwidth dimension ratio (BDR) value to confirm wideband characteristic with compact structure and confirming the desired bandwidth of SWB antenna using fractional usable bandwidth (FBW) and bandwidth ratio (RB).

e. Gain

Gain of an antenna is closely related to the directivity, which is a quantity related to the efficiency of the antenna and its directional capability. Gain of an antenna (in a given direction) is the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. This could be defined as absolute gain.

There is also relative gain, which is the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction. The power input must be the same for both antennas. The reference antenna is usually a dipole, horn, or any other antenna whose gain can be calculated or it is known [10].



f. Radiation Pattern

Radiation pattern is a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization. There are various parts of a radiation pattern defined as lobes, which may be classified into major or main, minor, side, and back lobes [10].

g. Return Loss

Return loss is a way of expressing the mismatch between a transmission line and the destination it feeds. Return loss is the ratio of the signal level that returns back, relative to the signal level that came from the signal source. Return loss must be must be lower than -10 dB in the entire band of frequency [2].

h. Bandwidth

The bandwidth can be considered to be the range of frequencies, on either side of a operating frequency (usually the resonance frequency for a dipole), where the antenna characteristics are within an acceptable value of those at the operating frequency [10]. Bandwidth of the antenna can be determined in terms of fractional usable bandwidth and bandwidth ratio. Fractional usable bandwidth (FBW) is a measure of bandwith with respect to centre frequency whereas bandwidth ratio (RB) is a comparison of lower and upper frequency limit. Higher the FBW percentage, broader the bandwidth of antenna achieved. There is also bandwidth dimension ratio (BDR) which measure of fractional usable bandwidth provided per electrical unit area. A high value of BDR in antenna designing is desired to confirm wideband antenna characteristics with compact structure [2].

III. METHOD

The design of the antenna in this undergraduate thesis is a slotted planar antenna with circular patch, tapered CPW feed and spline-curved ground plane. There is some stages to be conducted before the final model of the antenna. The stages are can be seen in Figure 3, antenna model (1) which designing the initial CPW feed with circular patch antenna, then antenna model (2) tapering the CPW feedline, the third stage is antenna model (3) which design the ground plane into spline-curved ground plane, and the last stage is antenna model (4) designing the slot into the patch and the groundplane. The last method is to widen the bandwidth, especially focusing on the lower frequency of the antenna.

Fig. 3. Antenna Model (1); Antenna Model (2); Antenna Model (3); Antenna Model (4)

The proposed antenna specifications are microstrip SWB antennas with circular patches with modified coplanar waveguide (CPW) feedline and spline curved ground plane using rectangular slot. The proposed design is a super wideband (SWB) antenna which should be operate in a bandwidth ratio equal or greater than 10:1 [1], while this antenna expected to be operated in 1-30 GHz. The antenna is designed on FR4 substrate material with dielectric constant (ε_r) of 4.3 and substrate thickness (h) 1.6 mm (single sided copper layer). The material used is copper because it is a good conductor with dielectric constant (ε_r) of 1 and substrate thickness (h) of 0.035 mm.

Table 1. The Specification of The Antenna

Parameter	Specification
Operating Frequency	1 – 30 GHz
Return Loss	≤ -10 dB
Gain	≤ 0 dBi
Antenna Impedance	50 Ω
Bandwidth	SWB

a. Antenna Model 1

The initial antenna designing process must be conducted as the foundation for the final expected antenna model. The initial antenna model can be seen in Figure 3. The comparison between initial and optimization antenna dimension can be seen in Table

Table 2. Antennna Model 2 Before and After Optimization

	Value (mm)		
Variable	**Initial**	**Optimization**	**Information**
Xsub	40	40	Width of the substrate
Ysub	50	50	Length of the substrate
Zsub	1.6	1.6	Thickness of the substrate
Xel	9.13	9.13	Patch radius
Lfd1	29.17	29.17	Length of the groundplane
Lfd2	0.784	0.784	Length of the feed extension
Wfd1	1.2	1.03556	Feedline width
Wfd2	1.2	1.03556	Feedline width near the patch
Xgr1	0.7	0.7	Distance between the mid feedline and the edge of groundplane near the feedline
Xgr2	1.55	1.55	Distance between the mid feedline and the cutting of the peak of groundplane

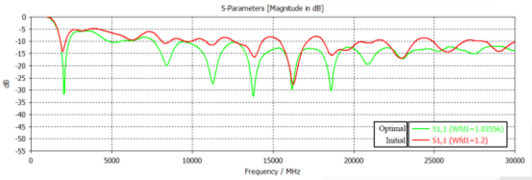


Fig. 4. Return Loss Comparison Between Initial Dimension (Red) and The Optimization (Green) of *Wfd1*.

It can be seen from Figure 4 that the return loss of the initial dimension still dominated with return loss value $\succ -10\ dB$. Then the optimization process on the width of the feedline conducted. Using the optimization algorithm of CMA Evolution Strategy in CST software, with sigma value of 0.5 and random seed of 1, the value of *Wfd* is obtained 1.03556 mm (the optimization target of $Wfd1 > 1\ mm$, with consideration of the SMA connector size if the antenna realized). From the optimization result this optimized initial model obtained triple-band frequency in frequency band of 1.8176 - 2.3573 GHz, 4.8191 - 5.5637 GHz, 7.5933 - 30 GHz. It can be concluded from the optimization process that the more narrower the width of the feedline the deeper the overall return loss minimum. The updated dimension can be seen in Table 2.

b. Antenna Model 2

The next optimization process conducted is implementing the tapered feedline method. This method expected to widen the bandwidth more. As shown in Figure 3, the modification process is the narrowing dimension on the *Wfd2*, so the dimension on *Wfd2<Wfd1*. The initial value of the *Wfd2* is 0.7 mm, as shown in Table 3. The result comparison can be seen in Figure 5. The comparison between initial and optimization antenna dimension can be seen in Table 3.

Table 3. Antennna Model 2 Before and After Optimization

	Value (mm)		
Variable	**Initial**	**Optimization**	**Information**
Xsub	40	40	Width of the substrate
Ysub	50	50	Length of the substrate
Zsub	1.6	1.6	Thickness of the substrate
Xel	9.13	9.13	Patch radius
Lfd1	29.17	29.17	Length of the groundplane
Lfd2	0.784	0.784	Length of the feed extension
Wfd1	1.03556	1.03556	Feedline width
Wfd2	0.7	0.56	Feedline width near the patch
Xgr1	0.7	0.7	Distance between the mid feedline and the edge of groundplane near the feedline
Xgr2	1.55	1.55	Distance between the mid feedline and the cutting of the peak of groundplane

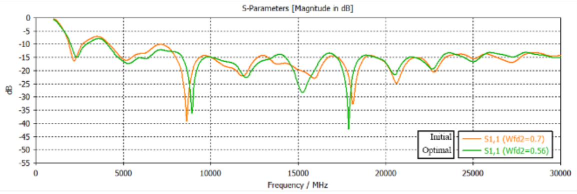


Fig. 5. Return Loss Comparison Between Initial Dimension (Orange) and The Optimization (Green) of *Wfd2*.

	Value (mm)		
Variable	**Initial**	**Optimization**	**Information**
Xsub	40	40	Width of the substrate
Ysub	50	50	Length of the substrate
Zsub	1.6	1.6	Thickness of the substrate
Xel	9.13	9.13	Patch radius
Lfd1	29.17	29.17	Length of the groundplane
Lfd2	0.784	0.784	Length of the feed extension
Wfd1	1.03556	1.03556	Feedline width
Wfd2	0.7	0.56	Feedline width near the patch
Xgr1	0.7	0.7	Distance between the mid feedline and the edge of groundplane near the feedline
Xgr2	1.55	1.55	Distance between the mid feedline and the cutting of the peak of groundplane
Xgr3	1.55 + 9 = 10.55	1.55 + 11.8956 = 13.4456	Distance between the mid feedline and the curved spline point at the groundplane (*x* coordinate)
Cgr	6.5	6.5 (Optimized)	Distance between the groundplane peak and the curved spline point at the groundplane (*y* coordinate)

Using the optimization algorithm of Trust Region Framework in CST software, with sigma value of 0.2, the value of *Wfd2* is obtained 0.56 mm. From the optimization result, can be seen also in Figure 5, the return loss minimum of the optimized result is deeper than the initial result and the return loss maximum of the optimized result is lower than the initial result which also means the bandwidth of the optimized result is wider. The optimized tapered feedline antenna model obtained dual-band frequency in frequency band of 1.9965 - 2.8892 GHz and 4.0795 - 30 GHz. It can be concluded from the optimization process that the more narrower the *Wfd2*, the updated dimension can be seen in Table 3, the lower the minimum return loss and the maximum return loss which means the wider the bandwidth. It can be concluded also that the modification of the feedline become tapered, the triple-band frequency can be turned into dual-band frequency.

c. Antenna Model 3

The next optimization process conducted is implementing the curved spline method on the groundplane. This method also expected to widen the bandwidth more. The result comparison can be seen in Figure 6. The comparison between initial and optimization antenna dimension can be seen in Table 4. There is three addition of variable which is *Dgr*, *Xgr3* and *Cgr* that the two last variables consecutively representing the *x* and *y* coordinate of the dimension. As shown in Figure 3, the modification process is on the outer wing of the groundplane using the curved spline method on variable *Xgr3* and *Cgr*. The initial value of the *Dgr* is 9 mm and *Cgr* is 6.5 mm as shown in Table 4. The *Dgr* variable function is for equation (7).

$$\mathrm{Xgr3} = \mathrm{Xgr2} + \mathrm{Dgr} \qquad (7)$$

Table 4. Antennna Model 3 Before and After Optimization

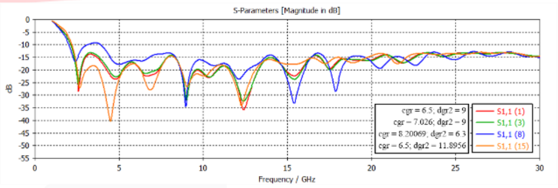


Fig. 6. Return Loss Comparison Between Initial Dimension and The Optimization Dimension of *Cgr* and *Dgr*.

Using the optimization algorithm of Trust Region Framework in CST software, with sigma value of 0.2, the value of *Cgr* and *Dgr* is obtained consecutively 6.5 mm and 11.8956 mm. From the optimization result can be seen in Figure 6, more smaller the value of Cgr and the more larger the value of Dgr, the lower the minimum return loss and the maximum return loss which means the wider the bandwidth. The optimized curved spline antenna model obtained single-band frequency in frequency band of 2.1994 - 30 GHz.

d. Antenna Model 4

The next optimization process conducted is inserting the slot on the groundplane and patch. This method also expected to deepen the return loss and widen the lower frequency range. There is two addition of variable which is *WS* and *LS* consecutively representing the width and the length of the slot. As shown in Figure 3, the modification process is the addition of slot on the patch and the groundplane symmetrically. The initial value of the *WS* is 1.2 mm and *LS* is 6 mm as shown in Table 5. The result comparison can be seen in Figure 7. The comparison between initial and optimization antenna dimension can be seen in Table 5.

Table 5. Antennna Model 4 Before and After Optimization

	Value (mm)		
Variable	Initial	Optimization	Information
Xsub	40	40	Width of the substrate
Ysub	50	50	Length of the substrate
Zsub	1.6	1.6	Thickness of the substrate
Xel	9.13	9.13	Patch radius
Lfd1	29.17	29.17	Length of the groundplane
Lfd2	0.784	0.784	Length of the feed extension
Wfd1	1.03556	1.03556	Feedline width
Wfd2	0.7	0.56	Feedline width near the patch
Xgr1	0.7	0.7	Distance between the mid feedline and the edge of groundplane near the feedline
Xgr2	1.55	1.55	Distance between the mid feedline and the cutting of the peak of groundplane
Xgr3	1.55 + 9 = 10.55	1.55 + 11.8956 = 13.4456	Distance between the mid feedline and the curved spline point at the groundplane (*x* coordinate)
Cgr	6.5	6.5 (Optimized)	Distance between the groundplane peak and the curved spline point at the groundplane (*y* coordinate)
LS	6	5.85569	Length of the slot
WS	1.2	1.24326	Width of the slot

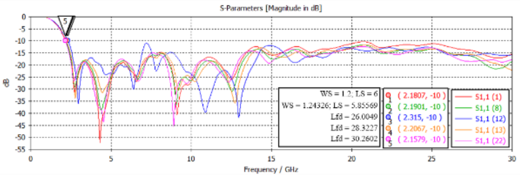


Fig. 7. Return loss comparison between initial dimension and the optimization dimension of *WS*, *LS*, and *Lfd*.

Using the optimization algorithm of CMA Evolution Strategy in CST software, with sigma value of 0.5 and random seed = 1, the value of *Lfd1*, *WS*, and LS is obtained consecutively 30.2602 mm, 1.24326 mm, and 5.85569 mm. The optimization process of the *WS* and *LS* results that the maximum return loss on the minimum frequency (1 GHz) is deeper so it potentially can have shifting on the lower frequency without much problem on the return loss. The *Lfd1* optimization process help the widen of the bandwidth. The optimized slotted antenna model obtained single-band frequency in frequency band of 2.1579 - 30 GHz. The frequency range is wider than the initial result at 2.1901 - 30 GHz and the overall return loss are deeper.

IV. SIMULATION RESULTS AND ANALYSIS

This chapter describes the analysis of the obtained result of the antenna simulation using the CST Studio software. The analyzed results are the optimized result from Model 1 to Model 4 return loss, the antenna bandwidth, the gain, and the radiation pattern. For the return loss and bandwidth, the SWB antenna can work properly if the return loss ≤ -10 dB over the entire range of the operating frequency. In this condition, SWB antenna must work properly in bandwidth ratio of 10:1 or more.

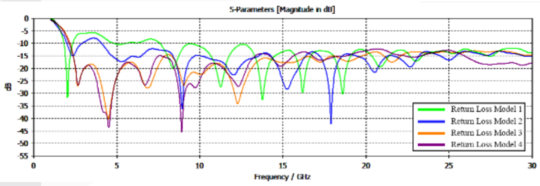


Fig. 8. Return Loss Comparison Between Every Optimized Antenna Model.

Can be seen in Figure 8, the overall return loss decreasing in every modification model which means the bandwidth is progressively widen. Every models of the antenna have the same similarity that is a constraint on achieving frequency band below 2 GHz. The frequency range on every optimization result still can continue above the maximum range of 30 GHz. The limited total cross-sectional dimensions of the antenna is the cause of the constraint on achieving the lower frequency, which the antenna use is $40 \times 50\ mm^2$.

Table 6. Minimum and Maximum Return Loss Comparison of Every Antenna Model.

Antenna Model	Min. Return Loss	Max. Return Loss
Model 1	-32.583019 dB	-0.25418747 dB
Model 2	-42.223129 dB	-0.61926628 dB
Model 3	-40.400522 dB	-0.60721184 dB
Model 4	-45.548214 dB	-0.51514088 dB

Table 7. Bandwidth Result of Every Antenna Model.

Antenna Model	Pass Band	Stop Band
Model 1	1.8176 - 2.3573 GHz 4.8191 - 5.5637 GHz 7.5933 - 30 GHz	1 - 1.8176 GHz 2.3573 - 4.8191 GHz 5.5637 - 7.5933 GHz
Model 2	1.9965 - 2.8892 GHz 4.0795 - 30 GHz	1 - 1.9965 GHz 2.8892 - 4.0795 GHz
Model 3	2.1994 - 30 GHz	1 - 2.1994 GHz
Model 4	2.1579 - 30 GHz	1 - 2.1579 GHz

In Table 7, Model 1 have achieve total bandwidth of 81.69% (triple-band), Model 2 in the amount of 92.46% (multi-band), Model 3 in the amount of 95.86% (single-band), Model 4 in the amount of 96.01% (single-band). From the return loss result and bandwidth result can be concluded that the SWB antenna characteristic can be achieved from the Model 3 which uses tapered feedline and curved spline groundplane with bandwidth ratio (RB) of 13.64:1 while the Model 4 which modify the patch and the groundplane with the insertion of slot can increase the bandwidth ratio (RB) to 13.91:1. Can be seen in Table 4.1, that the Model 4 (the insertion of slot) also can significantly deepen the minimum return loss to -45.5482 dB. The antenna also achieve a fractional bandwidth of 346.04% on 2.1579 - 30 GHz and bandwidth dimension ratio (BDR) of 535.79 that have the possibility to increase above the limit of 30 GHz.

Table 8. Gain Result of Every Antenna Model.

Antenna Model	Gain	Antenna Efficiency
Model 1	1.479 dBi at 2 GHz 1.859 dBi at 6 GHz 3.714 dBi at 10 GHz 3.826 dBi at 14 GHz 2.469 dBi at 18 GHz 3.393 dBi at 22 GHz 2.500 dBi at 26 GHz 0.4607 dBi at 30 GHz	78.05% 57.97% 64.48% 61.63% 41.21% 43.27% 31.65% 6.50%
Model 2	1.240 dBi at 2 GHz 2.282 dBi at 6 GHz 4.028 dBi at 10 GHz 3.546 dBi at 14 GHz 2.760 dBi at 18 GHz 3.716 dBi at 22 GHz 2.707 dBi at 26 GHz 0.7272 dBi at 30 GHz	62.15% 71.50% 70.25% 57.70% 46.26% 47.15% 34.05% 10.31%
Model 3	0.6930 dBi at 2 GHz 2.071 dBi at 6 GHz 3.728 dBi at 10 GHz 2.752 dBi at 14 GHz 2.435 dBi at 18 GHz 1.701 dBi at 22 GHz 1.773 dBi at 26 GHz 0.7416 dBi at 30 GHz	33.97% 70.68% 71.95% 55.37% 43.38% 29.65% 25.58% 10.62%
Model 4	0.7284 dBi	36.42%

	at 2 GHz 1.936 dBi at 6 GHz 3.764 dBi at 10 GHz 2.275 dBi at 14 GHz 2.512 dBi at 18 GHz 2.269 dBi at 22 GHz 3.223 dBi at 26 GHz 1.877 dBi at 30 GHz	69.36% 72.22% 47.74% 43.64% 35.93% 39.78% 23.75%

It can be seen in Table 8 that the efficiency of the antenna is lower in higher frequency. But the efficiency of the antenna on the higher frequency is more efficient in every modification step from Model 1 to Model 4. It can be concluded that the most efficient antenna is the Model 4 to work in higher frequency with gain of 0.7284 dBi at 2 GHz, 1.936 at 6 GHz, 3.764 dBi at 10 GHz, 2.275 dBi at 14 GHz, 2.512 dBi at 18 GHz, 2.269 dBi at 22 GHz, 3.223 dBi at 26 GHz, and 1.877 dBi at 30 GHz.

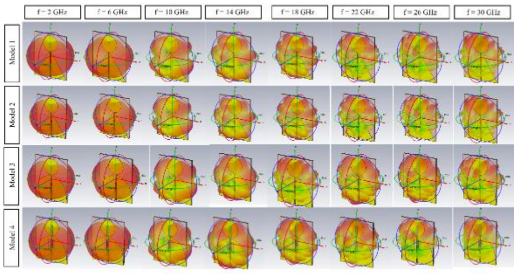


Fig. 9. Radiation Pattern Comparison of Every Antenna Model.

As shown in Figure 9, the modification from antenna Model 1 to Model 4 don't have significant differences in the radiation pattern. But the differences on every frequency sample can be seen every time the frequency goes higher, the direction of the pattern tend to approaching the *y* coordinate which mean the lower frequency have a tendency of omnidirectional while the higher frequency is unidirectional approaching the *y* coordinate.

V. CONCLUSION

In this undergraduate thesis, an attempt to widen the bandwidth of planar super wideband (SWB) antenna with coplanar waveguide and circular patch is proposed. The attempt to widen the bandwidth on the planar antenna is using gradual modification which is optimization of the initial CPW feed and circular patch antenna, tapered the feedline of the antenna, curved the spline of the groundplane, and insertion of slot on the antenna. From the simulation using the CST software analyzed, can be concluded that the planar SWB antenna has met the expected specification, 10:1 bandwidth ratio that work properly in 1 - 30 GHz which the result shows the working bandwidth is in 2.1579-30 GHz with bandwidth ratio of 13.91:1 and have the possibility to increase above the frequency range limit of 1 - 30 GHz. The antenna Model 1 (initial model) have achieve bandwidth of 81.69% (triple-band) from 1 - 30 GHz, Model 2 (tapered feedline) with total achievement bandwidth of 92.46% (dual-band) from 1-30 GHz, Model 3 (curved spline groundplane) with total achievement bandwidth of 95.86% (single-band) from 1-30 GHz, and Model 4 (insertion of slot) with total achievement bandwidth of 96.01% (single-band). The insertion of the slot affected the return loss significantly with deep minimum return loss of -45.5482 dB at Model 4 which can anticipate shifting on the bandwidth if the antenna is fabricated. The simulation result shows that the planar SWB antenna has bandwidth dimension ratio (BDR) of 535.79 and have the possibility to increasing above the limit of 30 GHz. The efficiency of the antenna is lower in higher frequency with the efficiency on the higher frequency become more efficient gradually from Model 1 to Model 4. The Model 4 is the most efficient in higher frequency with gain of 0.7284 dBi at 2 GHz, 1.936 at 6 GHz, 3.764 dBi at 10 GHz, 2.275 dBi at 14 GHz, 2.512 dBi at 18 GHz, 2.269 dBi at 22 GHz, 3.223 dBi at 26 GHz, and 1.877 dBi at 30 GHz. The modification from antenna Model 1 to Model 4 analyzed in sample frequency of 2 GHz, 6 GHz, 10 GHz, 14 GHz, 18 GHz, 22 GHz, 26 GHz, and 30 GHz don't have significant differences in the radiation pattern result, the differences can be seen on each frequency sample that the direction of the pattern tend to approaching the *y* coordinate every time the frequency goes higher which mean the lower frequency have a tendency of omnidirectional while the higher frequency is unidirectional approaching the *y* coordinate.

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