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Harmonic Suppressed Dipole Antenna with Size Reduction

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Abstract

Harmonic Suppressed Dipole Antenna with Size Reduction (HSDASR) offers a new method for designing a dipole antenna that incorporates size reduction and harmonic suppression. The rising need for small and effective antennas in contemporary communication systems demands creative ways to reduce physical dimensions and harmonic interference. Suppressing harmonic interference produced by non-linear components in the antenna system is the main goal. To reduce undesirable harmonics, the design makes use of stubs, harmonic trap structures, and other advanced methods. Achieving a small antenna size while preserving or improving performance metrics is a crucial objective. The use of methods of change the balun sizes from 100%, 75%, 50% and 25% is investigated in order to reduce size without sacrificing functionality. A thorough examination of previous studies on size reduction strategies, harmonic suppressed antennas and associated approaches is carried out. For modelling and simulating the proposed harmonic suppressed dipole antenna, simulation tools are used, such as CST Studio. The harmonic waves that were analyzed is at 0.9 GHz and 2.7 GHz. Operating signal is through 0 GHz until 3 GHz. Based on simulation results, the return loss, voltage standing wave ratio (VSWR), radiation pattern and gain was measured. The results show the function of adding stubs to the dipole antenna able to reduce around -20dB of harmonic. Based on the back to back balun, the return loss finds to be near to zero at 2.7 GHz and insertion loss finds to be less than -1dB. Using fabrication methods, the optimized design is turned into a prototype. The prototype is put through testing thus compare the results achieve with the simulation. The goal of the suggested size-reduction harmonic suppressed dipole antenna is to further the development of small and effective antenna designs. It is anticipated that the study will offer important new perspectives on how size reduction approaches and harmonic suppression strategies might be combined for real-world communication system applications.

1. Introduction

Antennas are used for a wide variety of applications, including radio and television broadcasting, mobile and wireless communication systems, satellite communication, radar systems, and many other fields [1]. The size and shape of an antenna depend on its intended application and the frequency of the electromagnetic waves. Antennas can be designed to operate over a wide range of frequencies, from very low frequencies (VLF) to extremely high frequencies (EHF) and beyond. The efficiency and performance of an antenna depend on its design, including its geometry, material, and the way it is positioned and oriented with respect to the source or receiver of the electromagnetic waves. The efficient suppression of harmonic interference by HSAs improves the quality of the signal [2]. The antenna makes sure that the signal is cleaner and more dependable when it transmits or receives by cutting down on undesired harmonic signals. Size of antenna that desired is always small and efficient with ability that same with bigger antenna [3]. The design of a Harmonic Suppressed Dipole Antenna with Size Reduction tackles harmonic interference issues while maintaining a small antenna size. The goal of the suggested antenna design is to address the problems caused by harmonic interference in contemporary communication applications while also making a contribution to the field of small and effective antenna systems. The research is anticipated further understanding of simultaneous size reduction and harmonic suppression in dipole antenna designs.

2. Materials and Methods

2.1 Flowchart

The flowchart of the development process is shown in Fig. 1. Briefly, it consists of the proposed harmonic suppression antenna and balun where it meets the specification and requirement design. Next, do basic configuration at 0.9 GHz. Parametric study and optimize the parameter thru simulation. Use CST to do the simulation and if the results needed achieve, move on to the next part which is configure the balun size. Simulate on four different kind of sizes balun and collect all the data. Proposed antenna and balun for 1a,1b,2a,2b,3a,3b,4a and 4b. Next, do the fabrication on all of the antenna. Measure and compare the actual results with simulation results.

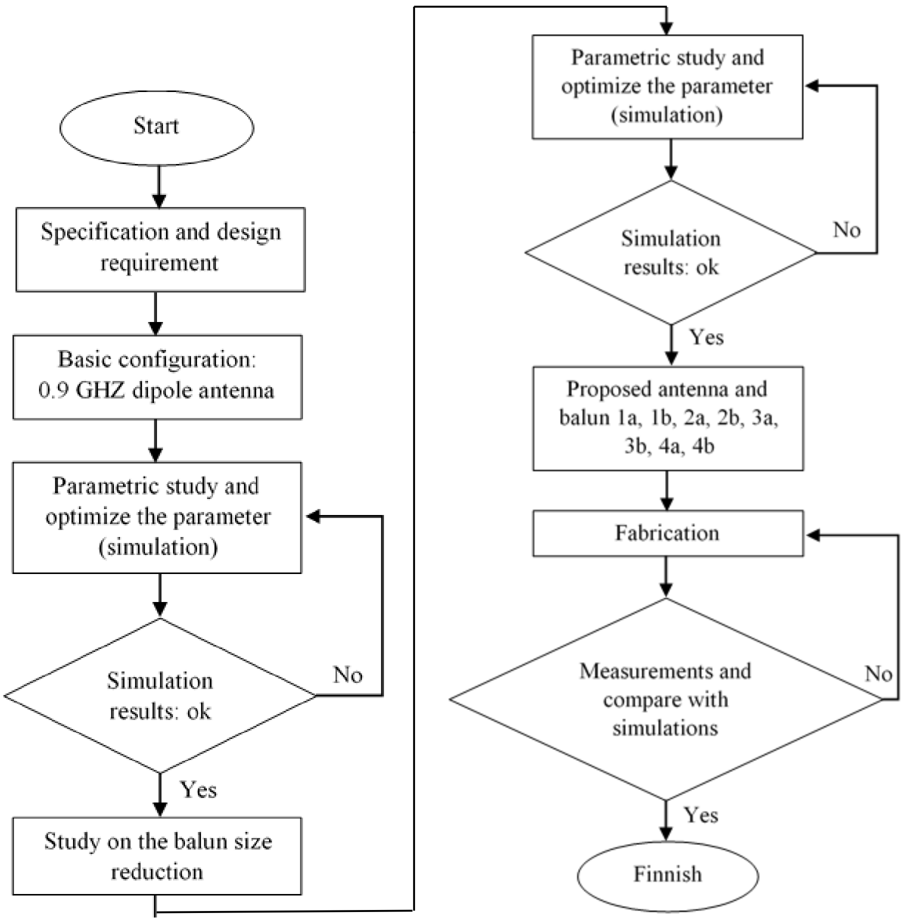
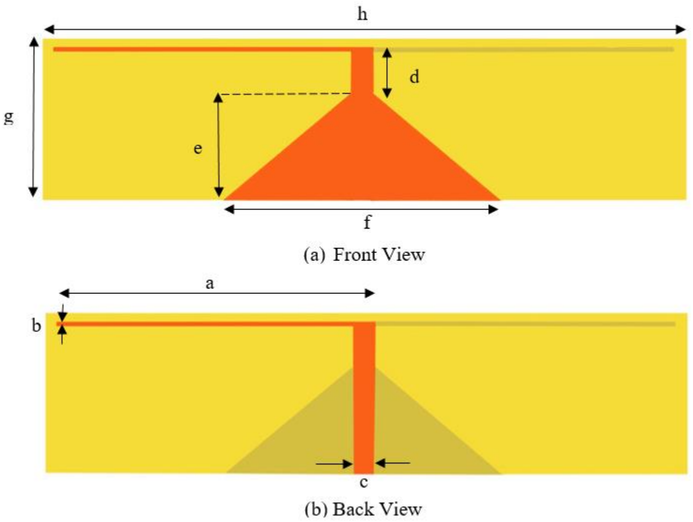


Fig. 1 *Flowchart*

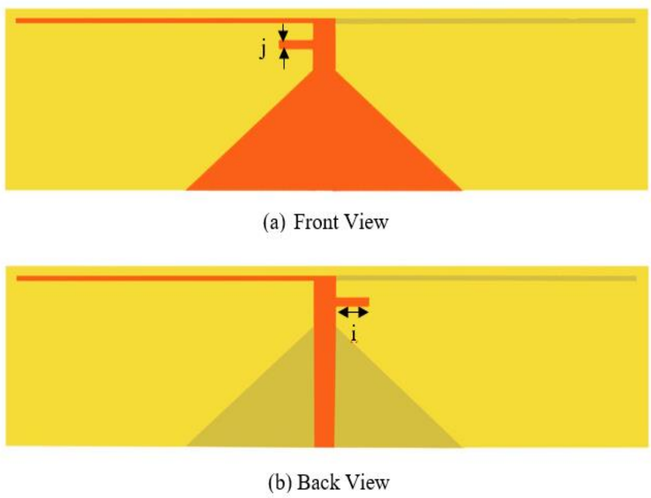
2.2 CST Simulation

CST software is used to design the antenna and simulate it to get all the data needed. There is a lot of option version of CST but the one that being used is CST Studio Suite 2021. The first thing right after opening the software. Create a template for planar antenna on the Project Template and choose antenna at the Microwave & RF/Optical option. There is option on settings that can configure all the readings that needed and adjust the frequency of antenna desired. The antenna that this project operate is at 0.9GHz and 2.7GHz. After select all the desired option, it will show new interface to draw and simulate the antenna. Modelling section will give the depth and function to build the antenna. Key in all the length of each parameter antenna with the substrate used. For this antenna, FR4 substrate is being used.

Fig. 2a below shows the antenna 1a. It uses FR4 material with thickness of 1.6mm. This dipole antenna has the arm length of 64mm with width of 1.5mm. The length of transmission line is 64mm with the width of 3mm. This antenna used a taper balun that has 54mm of height and 64mm of width for the back. Fig. 2b shows the antenna 1b. This antenna was same with 1a but it was added with stubs that has length of 13mm and width of 3mm. There are four different sizes of balun for both antennas shown in Fig. 2. Table 1 to 4 show the parameters of each antenna.



(a) ***without stub***



(b) ***with stub***

Fig. 2 *Dipole antenna*

Table 1 *Parameter antenna 1*

Parameter	a	b	c	d	e	f	g	h	i	j
Value (mm)	64	1.5	3	10	54	64	70	140	13	3

Table 2 *Parameter antenna 2*

Parameter	a	b	c	d	e	f	g	h	i	j
Value (mm)	64	1.5	3	10	40.5	48	70	140	13	3

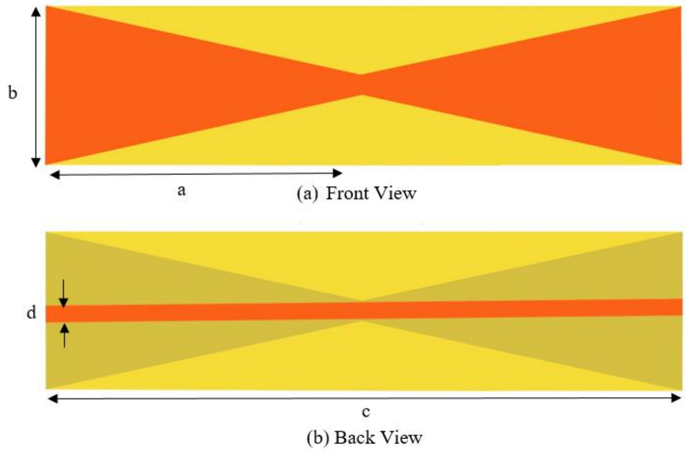
Table 3 *Parameter antenna 3*

Parameter	a	b	c	d	e	F	g	h	i	j
Value (mm)	64	1.5	3	10	27	32	70	140	13	3

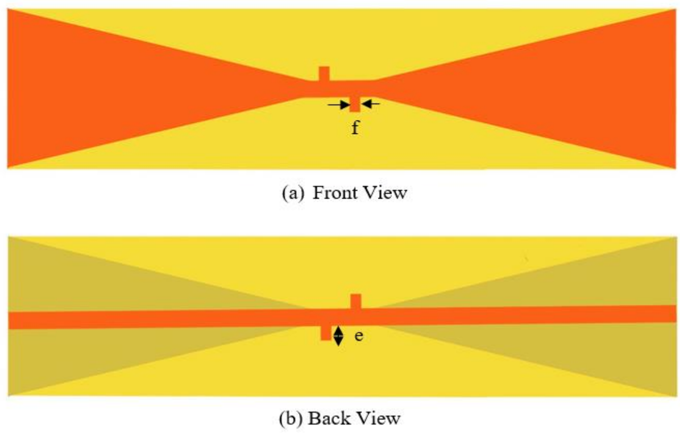
Table 4 *Parameter antenna 4*

Parameter	a	b	c	d	e	f	g	h	i	j
Value (mm)	64	1.5	3	10	13.5	16	70	140	13	3

Fig. 3a below shows the balun 1a. It uses FR4 material with thickness of 1.6mm. This back-to-back balun combine two same size of balun which has the length of 54mm and width of 64mm on the back view. While on the front view, it has transmission line of 108mm of length and 3mm of width. Figure 3b shows the balun 1b. The different between this balun and balun 1a is it was added harmonic trap with size of length 13mm and width of 3mm. Table 5 to 8 show the parameters of each antenna.



(a) ***without stub***



(b) ***with stub***

Fig. 3 *Balun*

Table 5 *Parameter balun 1*

Parameter	a	b	c	d	e	f
Value (mm)	54	64	108	3	13	3

Table 6 *Parameter balun 2*

Parameter	a	b	c	d	e	f
Value (mm)	40.5	48	81	3	13	3

Table 7 *Parameter balun 3*

Parameter	a	b	c	d	e	f
Value (mm)	27	32	54	3	13	3

Table 8 *Parameter balun 4*

Parameter	a	b	c	d	e	f
Value (mm)	13.5	16	27	3	13	3

2.3 Fabrication

Fig. 4 *Etching Machine*

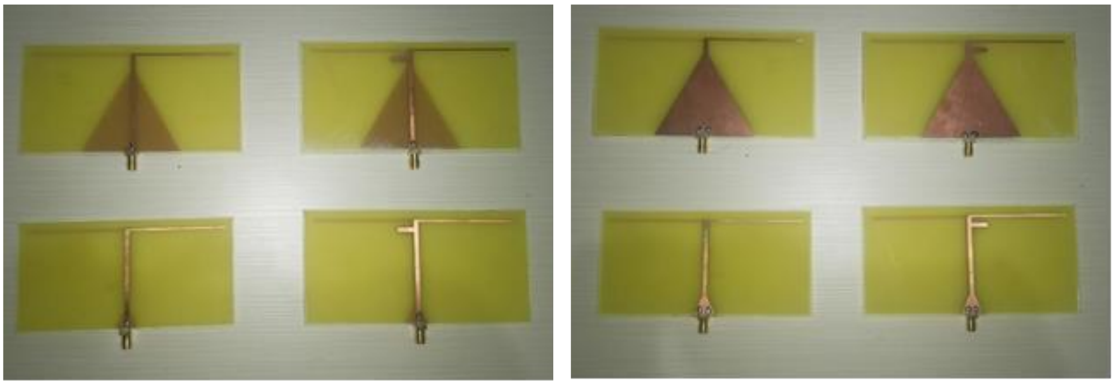


Fig. 5 *Fabricated Antenna (left) Front view (right) Back view*

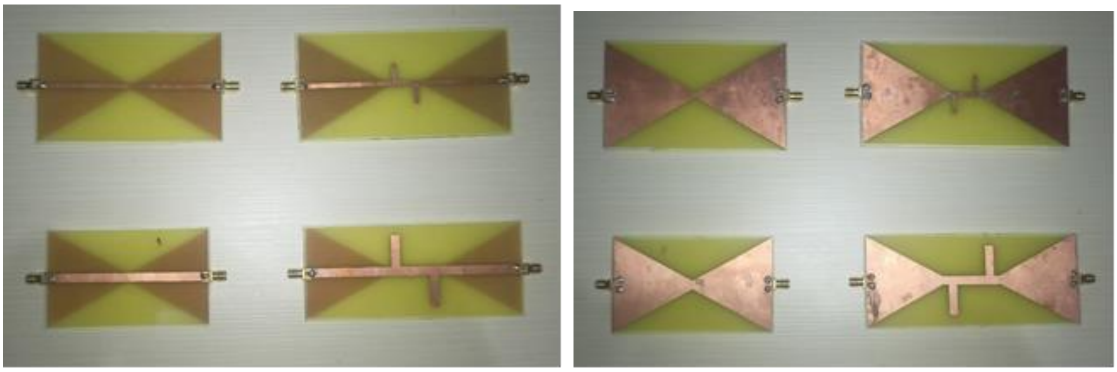


Fig. 6 *Fabricated Balun (left) Front view (right) Back view*

Fabrication antenna takes place at Advanced Printed Circuit Board Design Laboratory in University Tun Hussien Onn Malaysian (UTHM). It all start with converting file from CST to DXF. This because it can be read on another software which is AutoCAD. The method usually begins with a substrate material, which is usually FR4 (Flame Retardant 4), a dielectric substance that is frequently used in printed circuit boards (PCBs). The conductive layer is covered with a layer of photoresist. When exposed to light, photoresist, a substance with light sensitivity, changes. UV light is directed to the photoresist-coated substrate via a mask that creates the desired pattern. By preventing some regions from being exposed to light, the mask patterns the photoresist. Depending on the type of photoresist used, the exposed or unexposed portions are then removed from the substrate using a developer solution. This displays the intended pattern's underlying conductive layer. The exposed conductive material on the substrate is selectively removed using a chemical solution or plasma during the etching process using the etching machine shown in Fig. 4. The regions that are shielded by the residual photoresist do not change. It then need to be cut into desired antenna shape. SMA connectors were used to connect to this antenna. The connectors are shouldered to it carefully so that it not messed with the antenna. The already build antenna ready to be tested. Fig. 5 shows the fabricated antenna of antenna 1a, 1b, 4a and 4b. Fig. 6 shows the fabricated balun 1a, 1b, 4a and 4b.

2.4 Measurement Work

Measurement in real life and in simulation may differ a little bit but still the readings is not too far. After the fabrication works done, the next step is to do the real life testing on the antennas. The place to testing the antenna is at block F1 WARAS center. The testing of antenna need to be very precise that is why before starting the testing, it need to be calibrate the network analyzer machine as shown in the Fig. 7. The machine used is network analyzer brand Rohde & Schwarz. This machine able to run frequency range at 100 kHz to 20 GHz. It configures only 100kHz to 3GHz for this testing. It measures and analyze the performance characteristics of electrical networks and devices. It has two probes that run thru the antenna and shoe the S11 and S21 readings.

Fig. 7 *Network Analyzer*

3. Results and Discussion

3.1 Antenna

Fig. 8 shows the different in dB for both graphs. The red line is for without trap antenna while green line is for with trap antenna. The difference of S-Parameter is very clear at 2.7 GHz when the harmonic is shaved off by adding the trap. In Fig. 9, the VSWR for trap antenna was seen it takes less starting point from zero compared to the antenna without trap.

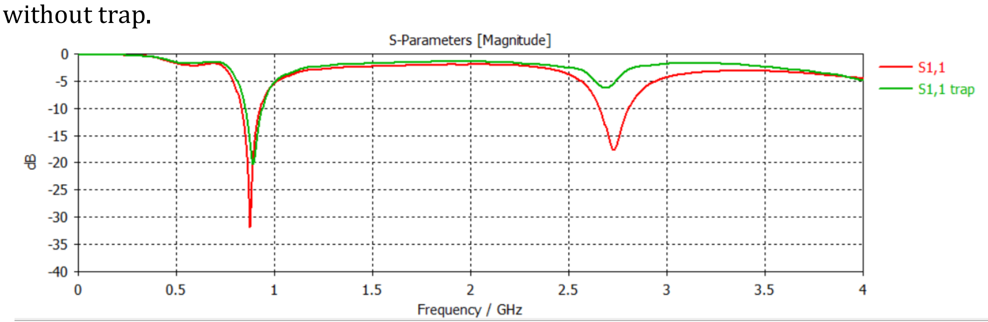


Fig. 8 *Comparison S-Parameter antenna 1a/1b*

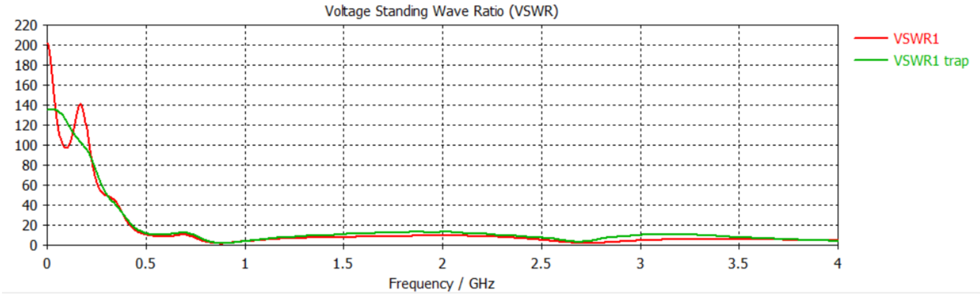


Fig. 9 *Comparison VSWR antenna 1a/1b*

Table 9 *Comparison Measurement Results*

Antenna	$f1$	S11	VSWR	$f2$	S11	VSWR
1a	0.9	-32	1	2.7	-18	1.3
1b	0.9	-20	1.4	2.7	-7	3
2a	0.9	-22	2	2.7	-29	1.5
2b	0.9	-25	1.6	2.7	-5	4
3a	0.9	-19	1.7	2.7	-20	2
3b	0.9	-21	1.9	2.7	-7	2.4
4a	0.9	-27	2	2.7	-30	1.8
4b	0.9	-14	1.8	2.7	-5	3.7

Table 9 shows the readings on S11 return loss for each antenna became smaller in dB. This because of the added harmonic trap which is stubs. It can suppress the harmonic at 2.7 GHz from -18 dB to -7 dB for antenna 1a and 1b. It shows a significant change with all the antenna after added the stubs.

3.2 Balun

Fig. 10 shows the S21 insertion loss balun 1a reflects the efficiency of power transfer through the balun. An insertion loss of -1 dB suggests that the balun is relatively efficient in transferring the signal from one port to the other. A lower insertion loss value is generally preferable, as it indicates less signal power loss during the transformation process. Fig. 11 shows the return loss of balun 1b. A return loss balun 1b is relatively high at -20 dB and implies that a significant portion of the incident signal is being transmitted through the balun rather than being reflected. This is generally desirable, indicating good impedance matching.

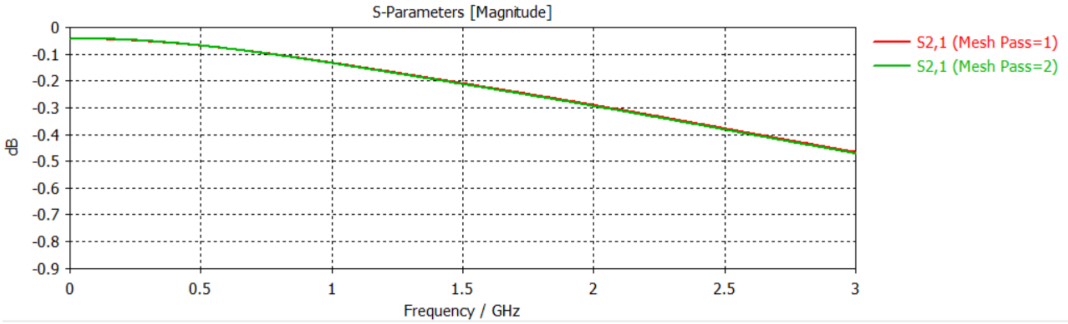


Fig. 10 *S21 insertion loss balun 1a*

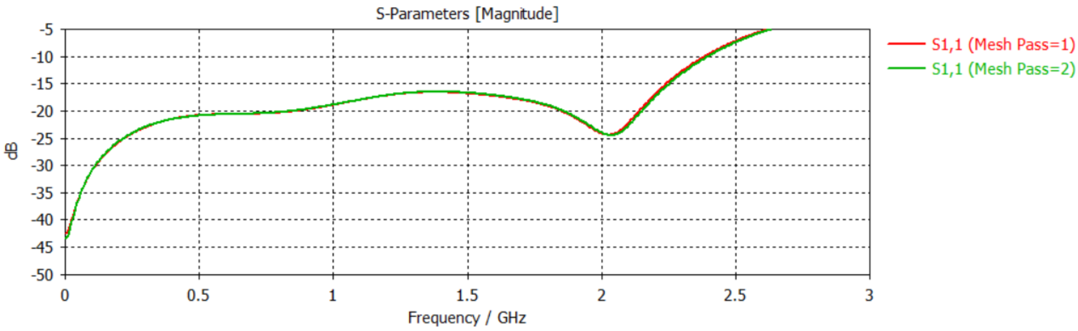


Fig. 11 *S11 return loss balun 1b*

3.3 Measurement results

Fig. 12 shows the measurement results for both antenna 1a and 1b. This measurement shows the different of the harmonic at 2.7 GHz. The dipole antenna able to remove the harmonic that happen in antenna 1a with added stubs in antenna 2b.

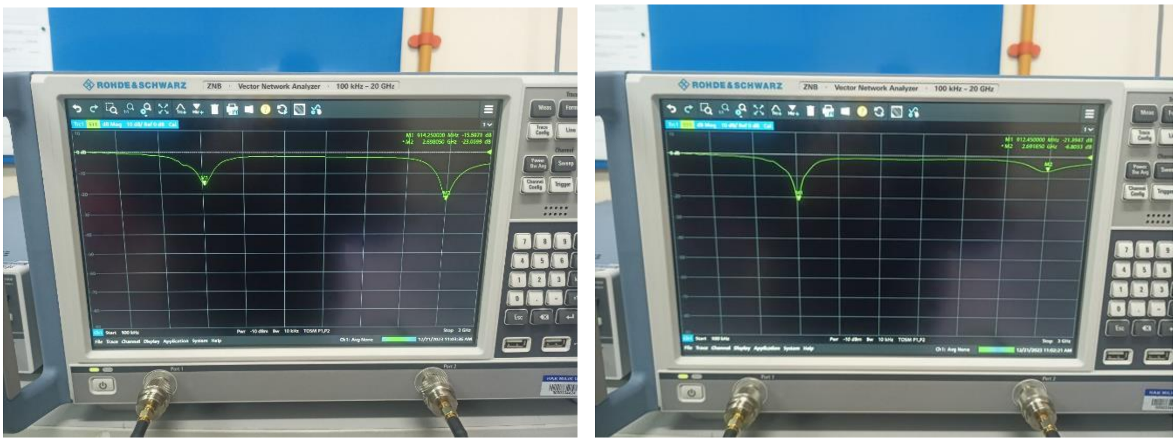


Fig. 12 *Measurement Results (left) Antenna 1a (right) Antenna 1b*

Table 10 shows the readings on S11 return loss for each antenna became smaller in dB. This because of the added harmonic trap which is stubs. It can suppress the harmonic at 2.7 GHz from -23 dB to -6 dB for antenna 1a and 1b. For antenna 4a and 4b, the suppressed harmonic at 2.7 GHz is from -21 dB to -6 dB. It shows that miniaturization works for change of balun size from 100% to 25%.

Table 10 *Comparison Measurement Results for fabricated antenna*

Antenna	$f1$	S11	$f2$	S11
1a	0.9	-15	2.7	-23
1b	0.9	-21	2.7	-6
4a	0.9	-13	2.7	-21
4b	0.9	-21	2.7	-6

Fig. 13 shows the balun 4a and balun 4b measurements. The S11 reflection coefficient shows the return loss of your amplifier resonate at 2.7GHz. It tells you the amount of power that reflects from port 1. The S21 transmission coefficient indicates the insertion loss of your amplifier at nearly -1dB. It tells you the transmission ratio in the forward direction.

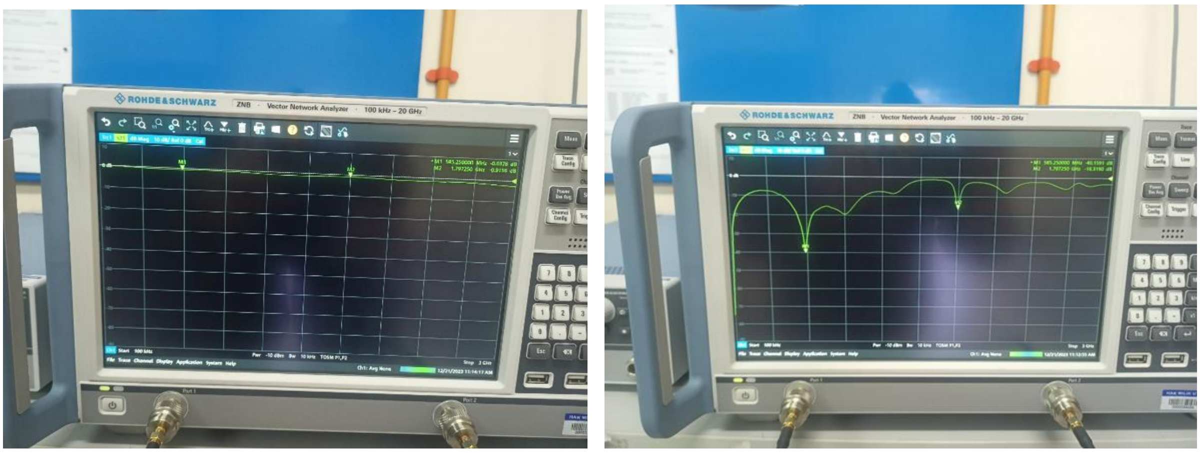


Fig. 13 *Measurement Results (left) Balun 4a (right) Balun 4b*

4. Conclusion

Harmonic suppression antennas (HSAs) are essential for maximizing wireless communication systems performance. These antennas are made to efficiently block harmonic signals. HSAs reduce harmonic signals and enhance signal quality by employing a variety of techniques like as filtering, resonating, and cancelling. All the objectives able to achieve from modelling and simulation using CST software. The design then fabricated which are then put through controlled testing to confirm the outcomes of simulations. Important factors in antenna design are the VSWR, return ross, and gain, which stand for impedance matching, signal reflection, and the capacity to focus or direct radiated power, respectively. All the results that acquired is very desired with the main objectives.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the completing of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

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