LAYOUT AN INEXPENSIVE ELLIPTICAL POLARIZED PRODUCTIVE INTEGRATED TRANSCEIVER

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ABSTRACT

This paper reveals a detailed modeling and simulation of active transceiver with elliptical polarization. Simplifying the complexity of merging these components: amplifiers, coupler, patch antenna and power divider using ADS (Advanced Digital System) software to have a system operates at 2.4GHz with less than -11dB return loss. By connecting the proposed transceiver components, it was found that antenna bandwidth was varying from 60o to 70o for both H and E plan. While a 3dB extra power was the gain of designed Active Transceiver above the Passive one.

Keywords: *Active Integrated Transceiver, Elliptically Polarization, 2.4ghz Frequency Band, Wireless, Parasite Components*

1. INTRODUCTION

A full package of antenna system included in one transceiver experienced is an increasing interest for most of the specialists who want to reduce the cost and size, and increase the overall system performance. Consequently, such a system is tremendously required for indoor WLAN (Wireless Local Area Network) at 2.4 GHz frequency band. A few good assumptive backgrounds had enriched this kind of paper with a large information on simulation actions and adjusting validation especially with the resultant return loss, gain and T-junction isolator between transmitted and received channels. Practically, an excellent prototype is not improved yet. Therefore, this paper will certainly prove that pragmatically as well as discuss the integration process step by step, until we reach the optimum combination between the both transmit and receive channels.

Items are identified are: four sides patch antenna in a diamond shape, T-junction electronic power divider, two Electronic MOSFET amplifier for Rx and Tx channels, and rat-race coupler. All these items simulated individually with ADS software from Agilent. Afterward we tend to match these items together and progressed through fabrication process to have a resonant frequency at 2.4GHz.

An elliptically polarization radiation pattern was obtained by simulation and measurements results. However, the antenna was tested in both transmitting and receiving mode after the items integration. This work has limitation in power consumption as well as long time of modeling.

Properly this research paper was arranged into eight sections: introduction, literature review, elements aspects specifications and design simulation, Full design assembly, fabrication process, radiation pattern, gain and power strength measurements results for passive elements, radiation pattern measurement for whole antenna analysis in the active case, validation of elliptical polarized antenna with the monopole antenna, and eventually we closed this article by a conclusion.

2. LITERATURE REVIEW

Recently, a great revolution happen in the field of active transceivers design, fully integrated package of communication system appeared in 1928 for the first time [1]. Just then, the electronic tube used with 1 MHz frequency carrier for wireless communication. In 60's and 70's of last century when transistors materialized for high frequency necessity of active transceivers was urgent, it has popped up to cover the markets needs at that time. Many benefits of active transceiver were discussed in [2]. More complexities were discussed in [3], However a functions of receiving components simultaneously integrated with the active transmitted part. The enterprise system in [3] was very interesting for many researchers at 2 GHz frequency carrier especially when full size had been reduced in the proposed design. Another design was proposed in [4], where diode operates at the top of antenna as a mixer, they interdicted the frequency mixer (FET), while Frequency mixer was used to cutoff higher frequencies. Antenna cavity was supported by special type of diodes named Schottky, by mixing radio with the power a good signal could be detected with minimum needs of connection devices. Proposed structure was highly interested for many purposes like radar system wireless communications and paging systems.

Linearly polarization and simultaneous progression was presented in [5], where Active elements are positively sighted with dual array operations in receiving and transmitting devices it resonant at 4GHz. linear polarization was the most important feature of the radiation pattern on the antenna array, So the transmitting channel was perpendicular with the receiving channel and channel offset could be different base on type of communication channel used.

An integrated hybrid design was mentioned in [6] where Integrated nonlinear Active component had been designed and analyzed for Transmitting and signal reception. The antenna resonant at 2 GHz and Bipolar Transistor was used for the circuit fabrication. While measurements were compared using two different finite domain time difference models. Good circular polarization was mentioned in the results with above than 25dB in the main beam location. A novel idea in [7] suggested separating the transceiver ports as much as possible in the integrated design. The design named Dual Polarized Microstrip patched antenna with a forward feeder, the forward feeder has significantly gave a good overall performance resultant from the isolation. The main reason behind this suggestion was to increase the performance by reducing the thermal noise level especially when single frequency was used.

A terrific optical lively antenna employing integrated FET inverted reel line repair, was provided in [8]. Good return loss and radiation patterns were very obvious in this design. However, the intensity of mixer diode was changed to get an impedance matching with the patch in order to produce 6dB gain. It was found that received signal to noise ratio (SNR) was function to rectified DC voltage while the FET Diode was off. The work defined in [9] was a circuit modulation influenced by Adjustable NP Diode encapsulated within a microstrip plate of antenna with parasitic components. These strengthen the antenna includes, depending on canal diode prejudice voltage. The outcomes extracted from antenna radiation pattern illustrate that a production of 5.8 MHz in bandwidth could be realized if a small modifications in tunnel diode is loaded. An active microstrip slot-ring antenna was proposed in [10] for the reception of FM microwave indication. Specialists discovered that monolithic behavior of an active slot-ring antenna as a lock-in amplifier. Hypothetical study coupled with fresh outcomes shows works well in a multi-channel setting because of the outstanding noise-squelching home of your shot Locked Gunn Oscillator.

Right now there had been several discussions specifically in [11] when a folded slot machine active point antenna pertaining to 5.8GHz radio applications is provided. It gifted a 10 dB return burning bandwidth of 5.65-6.55 GHz. The research workers claim that a fantastic agreement amongst the simulated and measured final results is discovered. It has great things about compact proportions and bigger bandwidth than previously reported structures.

Portrayal of active integrated antennas in terms of inters modulation distortion and compression place inside of a parallel plate cell was presented in [12]. Some decent commitment amongst the two solutions shows that the evaluation on the overall linearity behavior of arbitrary intricate integrated antennas and can function a contrasting tool in the event the common advised process may not be applied. Through integrating a good pair of zeroth-order resonators with some cross-coupled pair, initially a zeroth order oscillatory active built-in antenna (AIA) was developed in [13]. The proposed AIA, functional at 0.92 GHz, give an excellent DC-to-RF ratio of 52%, a Effective Isotropic Radiation power (EIRP) of 8.9 dBm, and a minimum phase noise of -124.7 dBc/Hz at a 1000 KHz offset adjacent to the carrier frequency. Some patch antenna and category B electrical power amplifier will be integrated pertaining to size decline and substantial power improved efficiency through harmonic suppression in [14]. Harmonic suppressing slits are achieved in a ways that ready and circularly polarization is supported. The mechanism in the slits is normally defined, and equally formula are identified and re-evaluated for usefulness acceptance. On top of results present that the harmonic suppression results in up to five per cent advancement for PAE and the antenna's diffusion develop is usually in no way troubled by increased harmonic controlling slits for anyone protected polarizations.

We present here a full design, simulated, evaluated and executed in a high level of functionality. The proposed design gives a low-cost full layout of transceiver depending on previous techniques viewed in the literature. It is found base on literature that a good evolution is possible to achieve and a promising design of transceiver base on active elements layout is an urgent need to fulfill industry requirements.

3. ELEMENTS ASPECTS, SPACIFICATIONS AND DESIGN SIMULATION

Designing an active integrated transceiver with a low cost is a target of this step, and then it is necessary to list down component of transceiver which are: Transistors, Coupler, Power divider and Circular Polarization Patch Antenna, Technology of amplifiers with basing circuit is empowered on this design using two transistors. Whereas the power divider designed with T-Junction shape to connect the input/output ports with the transceiver channels. An electronic circuit of Rat-race usually used to connect the emitter to the microstrip transmitter; in addition to that it is widely used to separate transition and reception channels [15][16].

Light weight and low profile and cost along with an acceptable radiation pattern are the good advantages of microstrip antenna. Accordingly in recent years an impressive research work emphasized on developing the production of these types of antennas. The Microstrip narrow bandwidth could be an authentic weakness due to the low profile characteristics. Therefore, it is important to mention that antenna bandwidth is a sub-factor of patch territory like: thickness, height, resonance frequency, and substrate dielectric constant [17][18].

In order to calculate microstrip width, the equation is given as follows in (1):

$$w = \frac{c}{2f\sqrt{\varepsilon_r}} \quad (1)$$

Where c is light speed, f = operating frequency at 2.40 GHz and εr = 4.60 .It is found that the width should be 2.9140 cm. Bt knowing that height h-1.6mm, Consequently we can calculate the Effectiveness of dielectric constant and Cutback for each edge Δ as following in (2) and (3):

$$\varepsilon_{eff} = \left(\frac{1}{2}\right)(\varepsilon_r + 1) + \frac{\varepsilon_r - 1}{2}\sqrt{\frac{1}{\left(1+\frac{10H}{W}\right)}} \quad (2)$$

We got: ε_{reff} = 4.2460,

$$\frac{\Delta}{H} = 0.4120\,\frac{\varepsilon_{eff} + 0.30W/H + 0.2620}{\varepsilon_{eff} - 0.2580W/H + 0.8130} \quad (3)$$

We got: Δ=0.073cm. In view of that we can easily bring to a close the length value using the following equation (4):

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta \quad (4)$$

Then, we got: L=2.8870cm

An ADS software is used to generate the following design in Figure 1, using the values issued using above mentioned formulas.

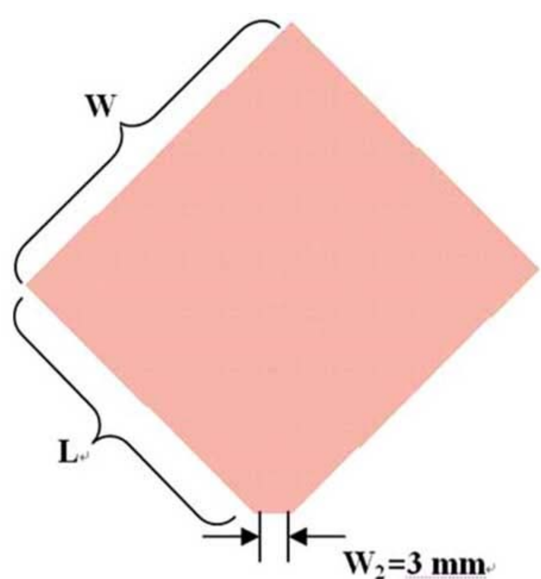

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Figure 1: Microstrip antenna has a rectangular shape.

With a 0.3cm edge cutting we can get the final diamond shape of our design as in Figure 2:

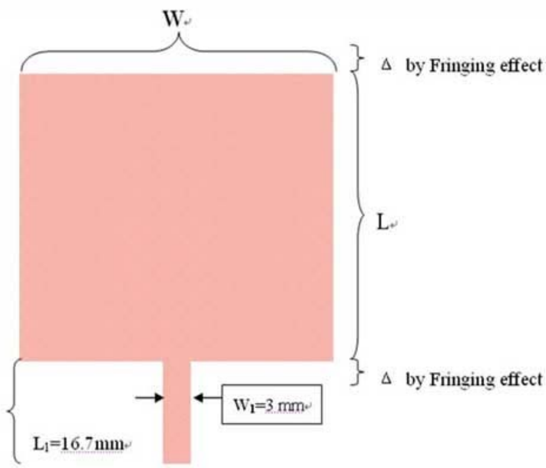

Figure 2: Diamond shape antenna with a cutting one corner.

The effects of *S11* finite method were definitely revealed in Figure 3 just for the square block antenna configuration. The antenna designed in a good schematic unit to reach -4.9dB at 2.4GHz frequency range accordingly a nice tuning happen to produce good layout.

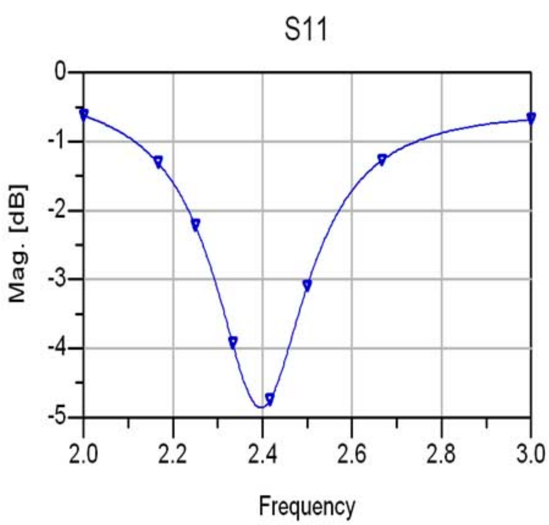

Figure 3: S11 simulation results for square antenna Layout

It was found base on simulation results appeared from Figure 2, that S_{11} is -3.780dB, and pulse signaling impedance was 122.00 Ohm (Z_L).

To boost up the return loss S_{11}, we applied the following equation (5):

$$S_{11} = \frac{Z_L - Z_0}{Z_L + Z_0} \quad (5)$$

A sector with a 25% of wave transformer introduced between transmission line and microstrip, this addition has improved the overall antenna return loss. The impedance of Z_L and Z_0 are reveled and impedance of quarter waving transformer Z_T is 78 Ohm. Referencing to these values by LineCalc prick in ADS, the approximate microstrip width of (W_2) and length of (L_2) we determined to be: W_2=1.22 millimeter, L_2 =17.3 millimeter.

The simulation results of the printed antenna layout and central circular polarization (S_{11}) were issued and demonstrated in Figure 4 and Figure 5, respectively.

With a width of microstrip width (*w*) of 30 millimeter, and length (*L*) of 28.5 millimeter, obtained Bandwidth (BW) was 135 MHz.

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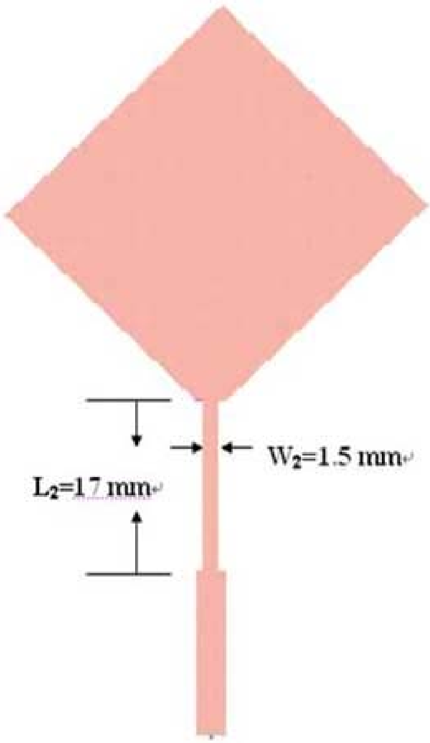

Figure 4: The Circular polarized antenna layout.

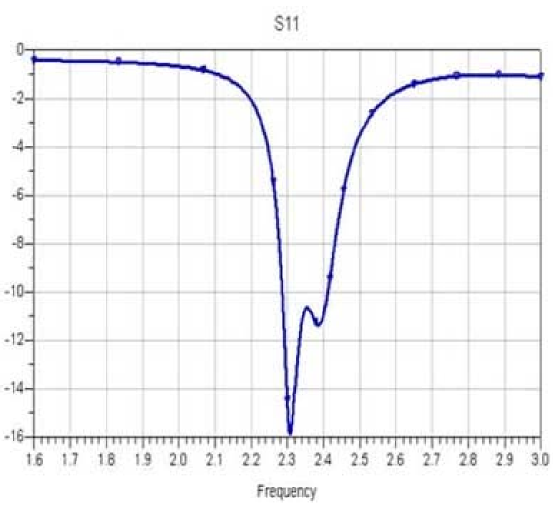

Figure 5: The return loss (S11) simulation results.

While in Figure 5 the obtained return loss reached to -16 dB, this return loss was functional within the range of 2.28 GHz until 2.41 GHz.

By simulating the square antenna using ADS software, it appears that the radiation pattern was not perfectly circular. That leads to a very obvious outcome which is the radiation pattern is more to be elliptical as shown in Figure 6.

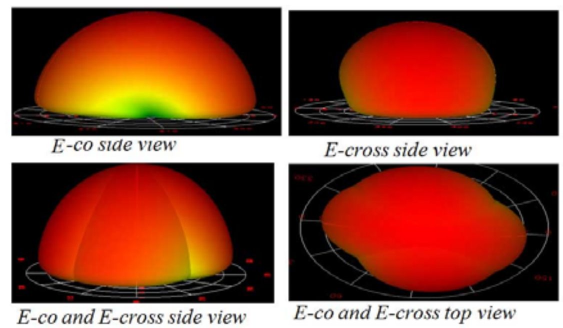

Figure 6: Elliptical polarization issued after simulated the radiation pattern of proposed square antenna.

This result in a fact is very effective in the antennas markets. However, having an elliptical radiation pattern makes the antenna behave to be a semi-omni direction. This is very favorable for indoor wireless local area communications.

Since a good results issued, times come to move for fabrication process, the FR4 materials had been used and etched using chemical materials to generate the parts of transmitter. Components were added to the design like couplers, mixers, modulators, Automatic signal level controller (ASLC), and double hybrids which are necessary to combine or separate signals. These components have a good voltage standing wave ratio, typical resistance and insertion loss with a good directivity over bandwidth [19].

With 180^0 (1π) phase difference between the output signals the Hybrid was designed which is similar to the 1/2 π except one different in phase.

Figure 7 shows the behavior of rat-race elements for 180^0 hybrid. As the Ring characteristic impedance calculated by $(2* Z_o)^{0.5}$ for -3dB hybrid, where Z_o is the calculated value of the input and output impedance ports.

However, using Rat-Race coupler will allow us to connect both transmitter and receiver channel simultaneously and keep these channels separated for the same antenna. Accordingly, Z_R (Ring impedance) will be calculated as: $(2* Z_o)^{0.5}= 70/71\ \Omega$. This value had been used in the simulation of ADS system.

The ring designed to have 0.15cm diameter, as well as the quarter wave length designed to have 1.72 cm. Accordingly we have obtained the ring radius to be 1.65 cm.

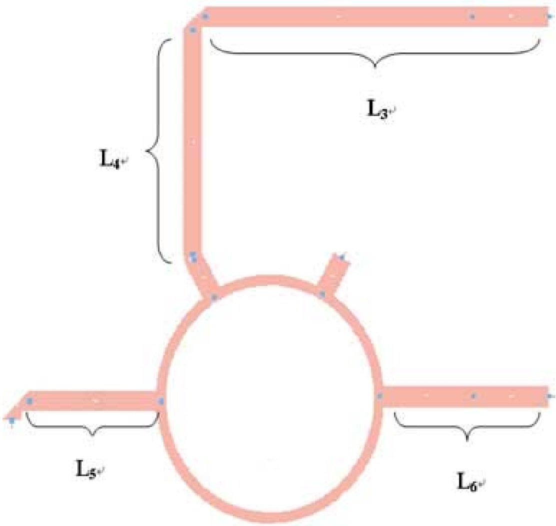

Figure 7: The Rat-race coupler design

Following collecting all basic calculations of rat-race metal coupler is simulated with schematic unit which is demonstrated in Figure 8 and presented in well done form as in figure 9 along with the proven physique.

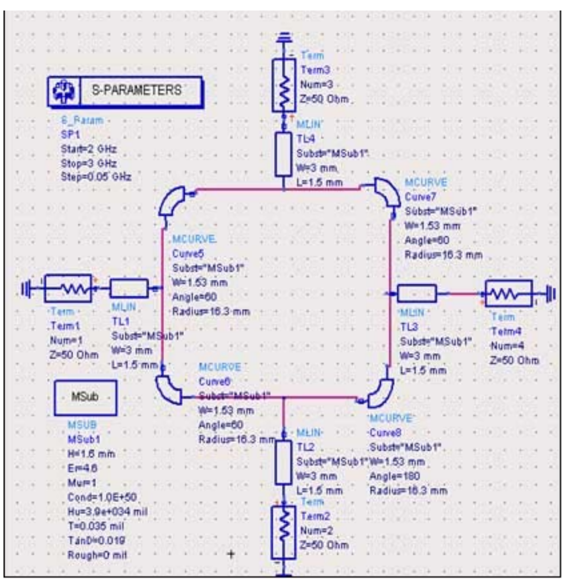

Figure 8 Schematic circuit mapping of Rat-race coupler.

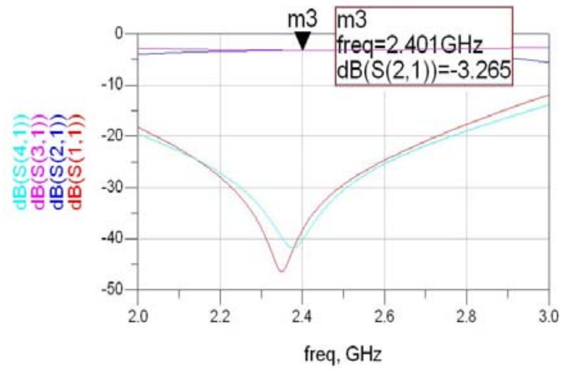

Figure 9: Schematic simulation to highlight the axial ratio effect of rat-race coupler.

The designed Ring width was 0.15 cm, while the quarter wavelength was calculated to be 1.724 cm, with a 3.292 cm diameter. The result of the residual incrimination in 3 ports length of the transmission line rely on the tuning options to achieve the toning compatibility in L_3 , L_4 ,L_5 ,L_6 ,W_3 and Radius. Final Simulation Results:

W_3 = 0.153 cm, L_3 = 5.226 cm

L_4 = 3.118 cm, L_5 = 2 cm

L_6 = 2.585 cm, Diameter = 3.296 cm

For rat-race coupler phase (s-parameters), it is desirable to mention that the S42 was -90. 3 intended for 2.4GHz volume transporter and 12 was varying around 90.24dB. These values show the best response to the design and style dimensions of rat-race coupler component. However, Rat-race component was fabricated using a FR4 materials and modeled microstrip measured using wet etching technique for the microstrip plate, and outcomes evaluated using Network Analyzer.

Upcoming element is definitely the T-Junction electrical power divider panel, the following factor is vital to link up the transmitted and received alerts combined together with the input/output plug-ins (ports). With this research implemented impedance intended for T-Junction electric source divider was $Z=70.7\Omega$, as determined priory. Although this benefit of impedance used that is crucial to note that one fourth wave transformer W4 was 0.15cm with 1.725cm of quarter trend length. Following collecting all of basic calculations of beliefs, T-junction electric divider panel is developed in sketch lining unit which is presented in Figure 10 and Layout simulation as displayed in Figure 11.

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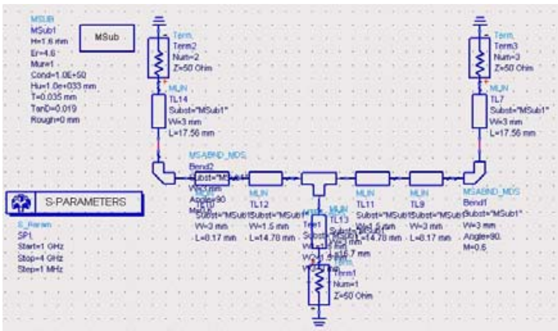

Figure 10: The schematic scheme of designed T-Junction produced by ADS software.

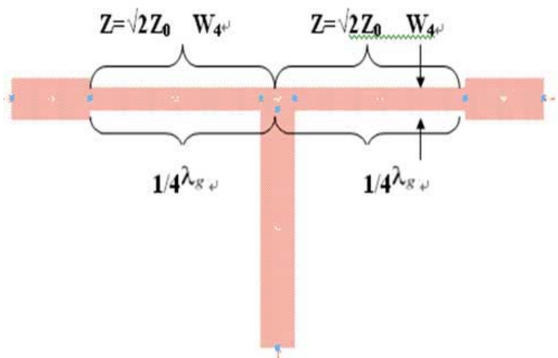

Figure 11: The Layout scheme of designed short T-Junction produced by ADS software.

To be able to match T-Junction electrical power divider panel considering the whole effective antenna enterprise, the diffusion line part should be higher which is portrayed in Figure 12, the tuning solutions for *L7, L8, L9, W4* the ranges changing though tuning finite result is normally found with Figure 13. However, Final Simulation Results for the extended mentioned parameters were: *W4* =0.15 cm, *L7* = 1.452 cm, *L8* = 0.843 cm, *L9* = 1.756 cm.

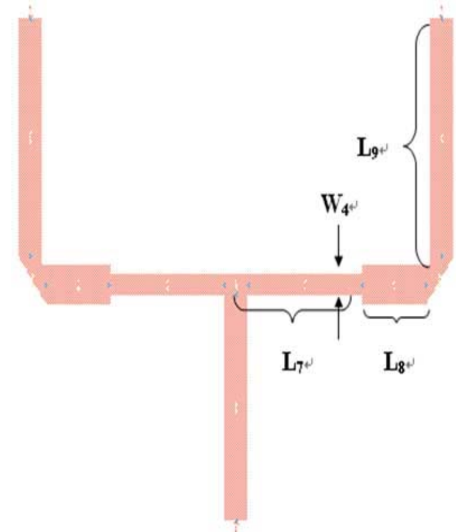

Figure 12: longer adjusted transmission line produced by ADS software.

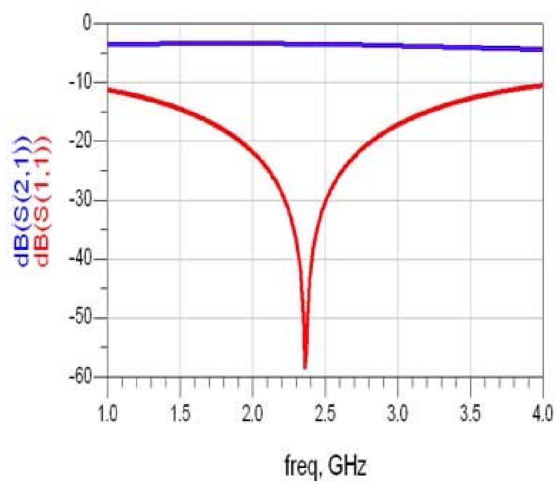

Figure 13: Scattering -parameters simulation results produced by ADS software for T-junction electronic power divider

Undoubtedly, *S21* and *S31* values are changing while *L8* is tuned, and *S21* and *S31* values are changing while *L7*, *L8*, *L9* is tuned.

T-junction electronic power divider panel can be then fabricated with a microstrip items (FR4) using soaked chemical etching approach, proper measurements done using Networking Analyzer to validate the results.

4. FULL DESIGN ASSEMBLY

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First combination done without adding patch antenna it was modeled by connecting the coupler to the amplifier. Nevertheless, the objective of such a combination was simulating two spited channels for the transmitting and reception. Whereas in second stage our objective was simulating the gain of transmitting channel as well as the gain of receiving channel using the transceiver which is the antenna.

The combining of coupler and amplifier may be taken out quickly in schematic style design since viewed with Figure 14, where rate-race coupler have a good position in four ports data item as well as the amplifier is definitely shaped simply by two jacks data item.

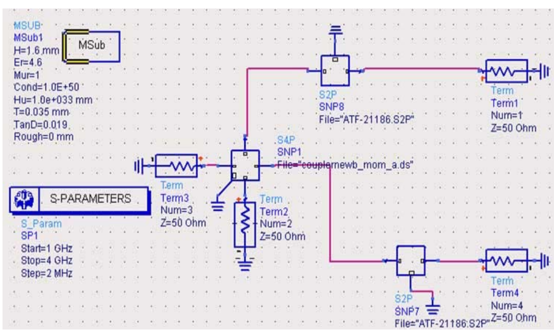

Figure 14: Coupler and amplifier combination of in ADS software

The coupler scattering parameters is imported as a data Item from the simulated graphs. The amplifier scattering parameters was an input into a Mini-circuit file first and then imported into Data Item from this file. Simulation result is shown in Figure 15**.**

The scattering parameters of coupler were brought in into Info Item through the ruse chart file. The amplifier scattering parameters were insight into Mini-circuit record first after which imported in to Information Item from this data file. Simulation effect is demonstrated in Figure 15.

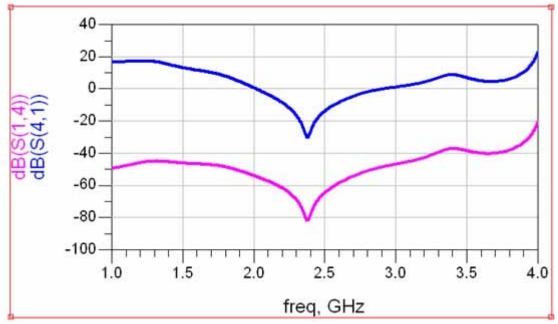

Figure 15: Simulation results of scattering parameters of coupler isolation

Combining all the designed components except the antenna was depicted in Figure 16, where a schematic sketch simulation used to elaborate the circuit components. T-junction power divider with a three ports had been adding to the simulation and the results of s- parameters could be extracted from figure 16.

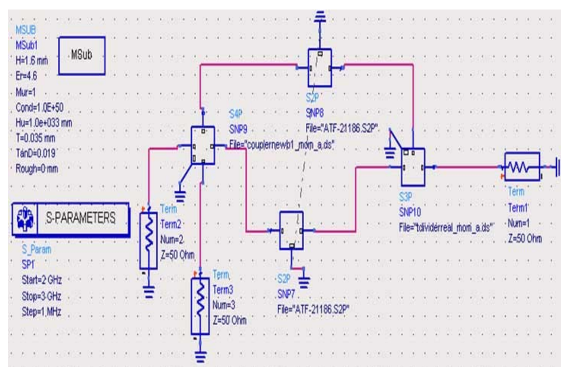

Figure 16: Whole circuit except antenna in ADS software

Figure 17 shows the abilities of obtaining good S-parameters after tuning *L9* to gain a good performance from the transmitted and receiving channel.

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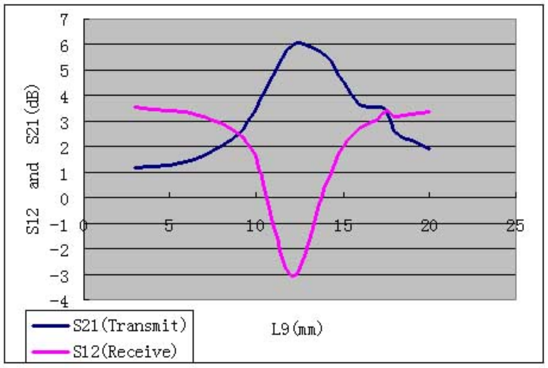

Figure 17: Adjustable L9 values to get the best gain the Rx and Tx channels.

The simulated axial ratio response throughout the resonant band is necessary to validate the performance of elliptically polarized antenna.

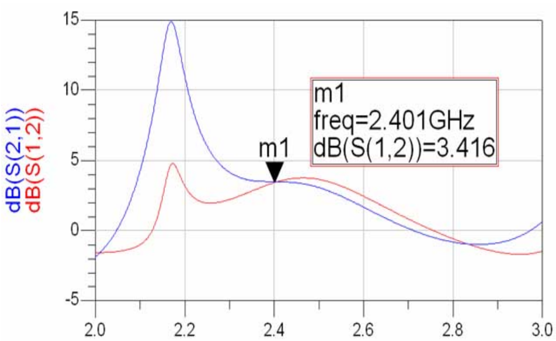

Figure 18: Tx and Rx gain simulation results.

5. FABRICATION OF LAYOUT AN INEXPENSIVE ELLIPTICAL POLARIZED PRODUCTIVE INTEGRATED TRANSCEIVER

The final layout an inexpensive elliptical polarized productive integrated transceiver is shown in figure 20, the passive plate patch, capacitor and resistor components ports and conductive elements are fixed by soldering on the FR4 plate.

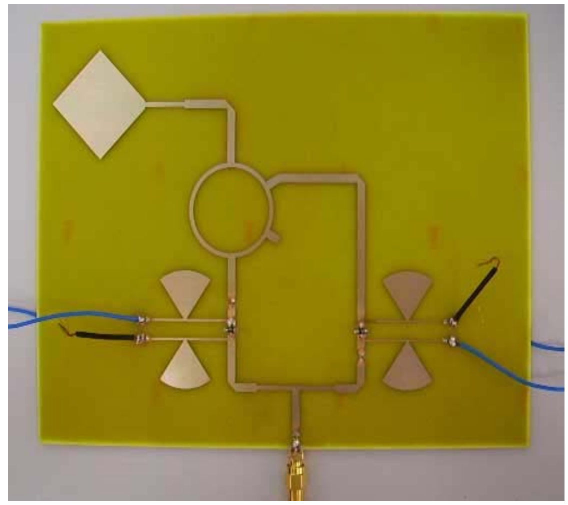

Figure 19: layout an inexpensive elliptical polarized productive integrated transceiver.

A wet chemical etching used to fabricate the Rat-race ring with the FR4 plate, while the measurements done using Marconi device and network Analyzer.

Adding the T-Junction power divider will facilitate the input and output ports and connect them to the received and transmit channel, it was found that best impedance could be *Z*=70.71 Ohm, while $Z= (2*Z_o)^{1/2}$. It is worthy to mentioned that the transformer quarter wave length of the transmitter (W_4) was 0.15 cm while the 1/4 wave length was 1.724cm.

By initiating all required formulas it was found that the scheme of T-junction power divider has the following values: *L9* = 1.756cm, *L7* = 1.452, W4 =0.151 cm, cm and *L8* = 0.843 cm, these dimensions values of T-Junction power divider were used in the fabrication process by wet etching technique and Network Analyzer. The design assembly is depending on adding the whole circuit without the antenna; combination will include the coupler and the amplifier to simulate the isolation of received and transmitted channels, then to find the channel proper gain.

6. RADIATION PATTERN, GAIN AND POWER STRENGTH MEASUREMENTS RESULTS FOR PASSIVE ELEMENTS

The final implementation of the Active Integrated antenna shows a good received signal strength index RSSI. As well as the radiation pattern had been tested inside the anechoic Chamber and the tested as shown in Figure 20.

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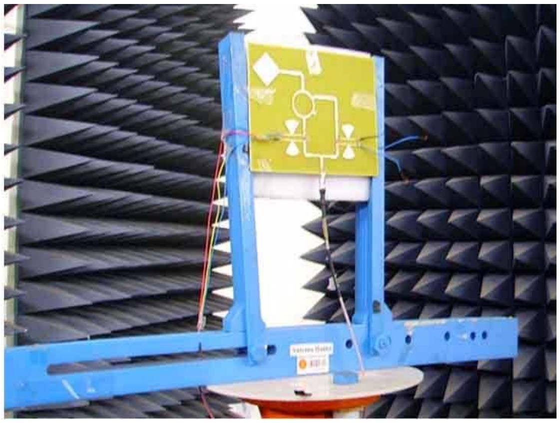

Figure 20: Measurement of antenna radiation pattern setup.

Figure 20 shows that Active antenna used as a transmitter and the signal received by a horn antenna (the reference antenna). This scenario will be reversed in a case when the active antenna used as a receiver. A DC motor mounted directly under the fabricated Integrated Active Antenna and used to give rotation torque and allow us to measure the resultant polarization [20].

Figure 21 and 22 show the measured radiation pattern of the fabricated active integrated antenna, we found a good and wide coverage can produced by shedding this antenna power on the anechoic Chamber area.

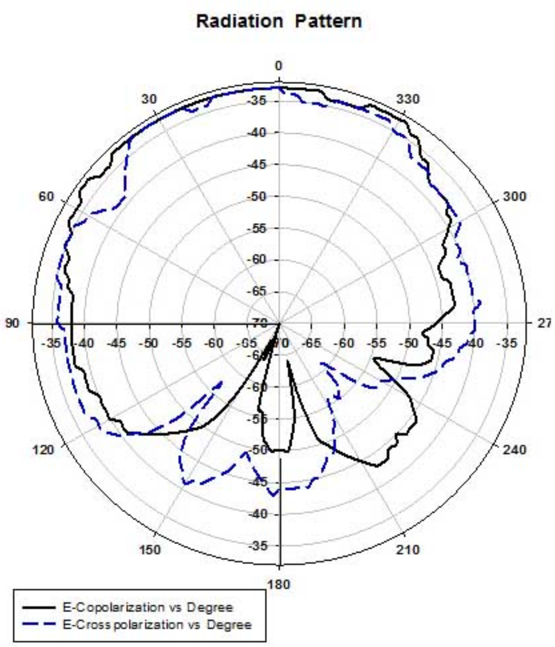

Figure 21: Radiation pattern of the Passive Antenna for E-copolarization

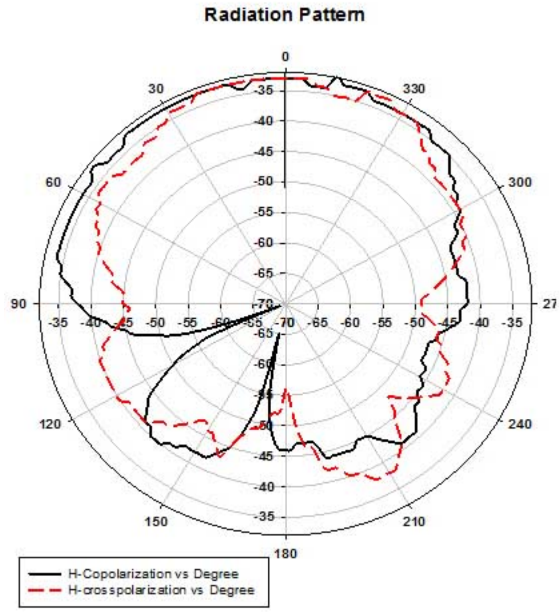

Figure 22: Radiation pattern of the Passive Antenna for H-copolarization.

Bothe H-Plane and E-Plan have 70^0 of Half Power Beam Width (HPBW). It is clear from the H-plane and E- plane that there are no much differences between both patterns, and we found that the co-polarization is very similar to the cross polarization which make us admit that this antenna is circular polarized antenna. Figure 23 shows the return loss *S11* of the circular polarized passive antenna was measured using the Network Analyzer.

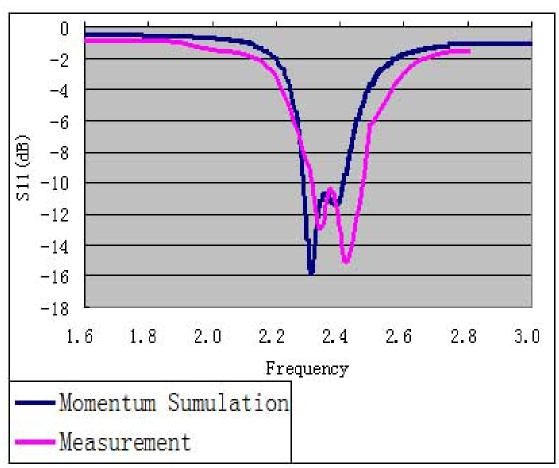

Figure 23: The measures Return loss in comparison with the simulated result.

As a good return loss result (less than -10dB) within 2.4Ghz, and more than 120MHz bandwidth shown in simulation and practical measurements we can say that this antenna shows a good performance

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and it is attractive for many applications. As a good outcomes obtained from ADS Simulation had shown an excellent harmonization with the fabricated design. The achieved return loss (S11) in ADS simulation was -22dB at centre frequency of 2.4GHz. On the other hand, bandwidth was improved in a better way. However, the phase different from port 4 until port 2 (-90°) and phase different from port 1 to port 2 (90°) is 180°. The obtained Return loss after measurements was -24dB at 2.4GHz, the phase difference from port 4 to port 2 (-107.5°) and port 1 to port 2 (77.5°) is 185° which is almost 180°.

Validating the estimated comes from the simulation using ADS by the reaction measurements after fabrication process a great result appeared. In term of Return loss, a good result of lower than -15.5 dB harvested at 2.4GHz with an impressive Bandwidth (BW). The measured gain from port 1 to port 2 and port 1 to port 3 was -4.6 dB (46.5%), which reflect a wise choice of material used because of good harmonization with the simulation results. The amplifier circuit was connected to 68 Ohm resistor and 1x10-10 Farad capacitor to an ATF transistor to achieve the bases, all together was soldered in one line and connected to the pitch.

7. RADIATION PATTERN MEASUREMENT FOR WHOLE ANTENNA ANALYSIS IN THE ACTIVE CASE

The whole system radiation pattern was demonstrated in Figure 24 and 25, for Active Integrated Antenna, and the measurements had been done inside the anechoic chamber.

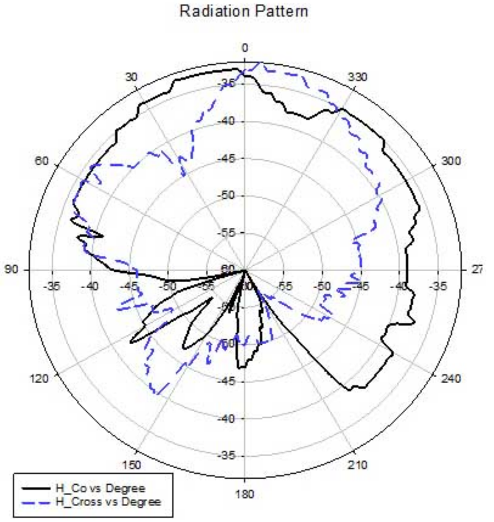

Figure 24. The H-plane of return loss in Active mode.

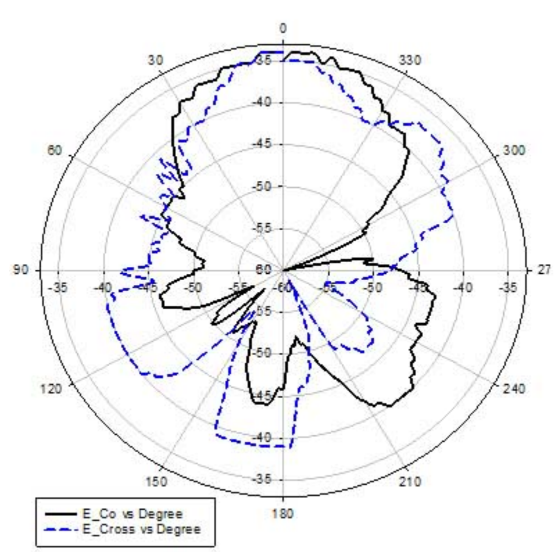

Figure 25. The E-plane of return loss in Active mode.

The Active mode radiation pattern analysis shown in Figure 24 and 25 emphasize that the antenna has an almost symmetrical cross polarization because both of H-curve and E-Curve are alike.

When a validation applied between active and passive results, we found that passive results are better because of the Transistor instability, which cause a reduction in the transmitted power at some points. For this Active antenna the HPBW as a transmitter was 67^0 for E-plan and 64^0 for H-Plan. On the reception side the HPBW was 65^0 in E-Plan and 62^0 for H-Plan.

8. VALIDATION OF ELLIPTICAL POLARIZED ANTENNA WITH THE MONOPOLE ANTENNA

Electronic Anechoic Chamber with network analyzer used to measure antenna gain and validate the measurements results with the monopole antenna as displayed in Figure 26 and Figure 27. On Figure 26 it is clearly that the broadcast and acquires gain is less than monopole antenna when the frequency is between 2GHz and 3GHz, and similarly there is a reduction by 4 dB than the monopole regarding 2.4 GHz. Within Figure 27, it appears that, active and passive antenna gain is generally reduced than monopole antenna by 2 dB which is more significant than recurring antenna in regard to 2.4GHz operating frequency.

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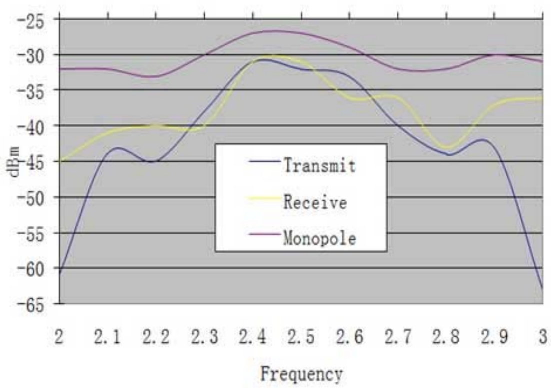

Figure 26: Comparing the gain of monopole antenna with the current active antenna gain.

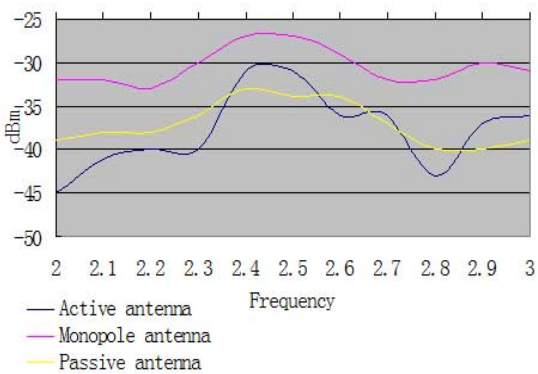

Figure 27: Comparing the gain of monopole antenna with the current active and passive antenna gain.

9. CONCLUSION

The aim of this research is in conformity with occurrence format on Integrated Microstrip Active Transceiver, T-junction Power Divider, special Rat-race Coupler, and Amplifier's Biasing with the utilization of ADS software, yet using these designs in accordance with construct prototype.

All those Prototypes have already been examined to check on their capability to produce successful, powerful and solid item. All designs had been simulated analyzed built fabricated and measured in a good form of integrated antenna. A good gain issued from the integration process, improving such a gain will lead to a very impressive technology would help to reduce the weaknesses of MIMO antennas systems. Ultimately, this research was specially designed and fabricated successfully on single plate intends is compatible with the planned objectives.

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