Design and Performance Analysis of a Directional Coupler for Wireless Application

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Abstract - Directional couplers are new technologies which help in implementing several wireless devices for example- mobile phone, a wireless LAN communication device, a communication device confirming to the Bluetooth standard etc. They also improves isolation factor as well as directivity and reduce the insertion loss.In this paper an updated results has been calculated by comparative study to the previous work in terms of isolation coefficient and return loss. In this paper the results are obtained best in hybrid line directional couplers for 0.1 GHz to 6 GHz for wireless applications. The third design is the improved design which successfully provides improved bandwidth, Insertion loss, Return loss S11 in lower range of RFID frequency. Here we get 0.1 GHz to 2.283 GHz operation with one band and another in 5 GHz to 6 GHz. Here we have a dual band of operation with bandwidth of 2283 MHz and 510 MHz at 1.6 GHz and 5.3 GHz respectively.

Index Terms—Directional Couplers, Return loss, Insertion Los, Coupling Factor, Isolation.

I. INTRODUCTION

The usage and designing of directional couplers is in such a way that the passing of energy from one provide coupled to other. This type of phenomena is helpful for microwave frequencies and in this work the use of directional couplers is to provide high performance in any modern wireless communication system, for the purpose of designing several circuits on that transmission lines are used. So, it can be say that for lumped components devices can be formed at very low frequency which can also contain audio frequency that is responsible for higher bands waveguide are-telephones, microwave frequency etc. There are several applications of directional coupler or power dividers respectively[1-3].

Overview of Directional Couplers

The directional couplers are used for the delivery purpose of the power which is used in microwave. The directional coupler are built using four ports indulged as-matched termination present at the upper with one auxiliary output which also has port 1 and port [4] [5].

The transmission of power is done in a way that the receiving side as well as the transmitted side need to have an idea about it whether the power value is higher or lower for the transmitted power. This is the main role of using directional couplers [6].

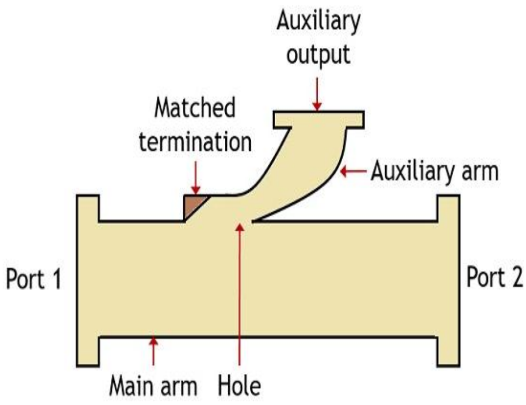

Figure 1: Two Ports Directional Coupler.

The overall working of this paper includes section I which is introduction of the directional couplers along with the uses of it in wireless communications. Section II is the literature survey. Section III is the problem identification in previous work. Section IV proposed methodology. Section V is the simulation setup and design. Section VI is the conclusion obtained from this work.

II. LITERATURE REVIEW

In this section we have explained various previous works on comparative basis.

In this paper author proposed [7] Forward-wave coupling exists between uniform symmetrical coupled lines if the even- and odd-mode phase velocities of the coupled lines are unequal. The design mechanism of symmetric and asymmetric broadband couplers is well established. A broadband coupler has been constructed using multi-mode resonator (MMR). The resonator primarily resonates in four distinct modes of frequencies. Out of these, three modes are responsible for broadening the operating band. Operating bandwidth may be tuned by the impedance ratio of the proposed resonator. The coupling is tunable by the gap between coupled transmission lines of the coupler. Finally, a forward-wave 10dB directional coupler ranging from 4 to 8 GHz has been designed. The design has advantages like single layer, without bond-wire and compact size.

In this paper [8] author explained about recently there is a trend for designing microwave components using differential excitation in contrary to the commonly known single ended-fed components. The differential technique features superior rejection of interfering signals, which by nature propagate equally in all conductors, thus are considered as common-mode signals. In this paper the proposed work is co-bounded with the exited directionally coupler which uses the balanced lines is shown. A new technology of an edge-coupled stripline is also proposed with the physical terminologies. This technique was first introduced by the multi-section design using asymmetric couplers.

In this paper [9] author proposed Branch-line directional couplers are well-known components in microwave electronics. Typically, such circuits are designed for single-ended operation, in which all the couplers' ports are excited with respect to the common ground potential. Recently there is a growing interest in design of differentially-fed microwave circuits due to their superior response in terms of common-mode interference rejection. The investigation results on the design of branch- line coupler have been presented. The coupler is designed as a differential circuit with the use of two-conductor substrate-integrated transmission-line technique. The four-branch topology has been employed in order to enhance the operational bandwidth, whereas the impedances of the transmission lines have been optimized to allow for their physical realization.

In this paper [10] author proposed anovel full-band square waveguide coupler configuration dependent on directional couplers which couple the TE10 and TE01 symmetrical modes in a square waveguide is introduced. This waveguide coupler is focused on the adjustment of polarization collectors.This is made out of a couple of rectangular waveguide directional couplers, which are turned 90° among them and both are coupled to the primary square waveguide through every single one of the square area dividers. The coupler covers the full recurrence band from 10 to 18.9 GHz. It has innate low cross-polarization, which permits acquiring any known circularly enraptured wave at a square waveguide when a sign is applied to the couplers. The created model of this coupler shows 31 dB of coupling, with levelness of ±3.8 dB and incredible cross polarization superior to 50 dB over the entire band.

III. PROBLEM DEFINITION

The size, directivity and operating bandwidth are major concern in any Directional Couplers designing. Therefore, there still exists a challenge to simultaneously obtain a compact size and preferable performance for Directional Couplers. These problems are rectify in this work by using hybrid line directional coupler.

IV. PROPOSEDDESIGN

The proposed designs of directional coupler are simulated on Ansys HFSS software with a frequency range of 0.1 GHz to 6 GHz for the all of the three designs. The best result is obtained in 3rd design in terms of bandwidth, return loss.

The simulation design is made up using FR4 substrate. The proposed Printed Directional Coupler design is 0.1 GHz to 6 GHz which is widely used for wireless Communication with higher bandwidth and compact size.

1st Design of Cross Couple Line Directional Coupler Model.

Result for 1st design of directional coupler model is tabled in table 1 in this section we analyze the performance of proposed Cross Couple Line coupler on the basis of coupling factor (S_{31}) which is used to calculate the ratio of coupled output power, isolation (S_{41}), Return Loss (S_{11}), Insertion Loss (S_{21}), Bandwidth (in MHz) and VSWR.

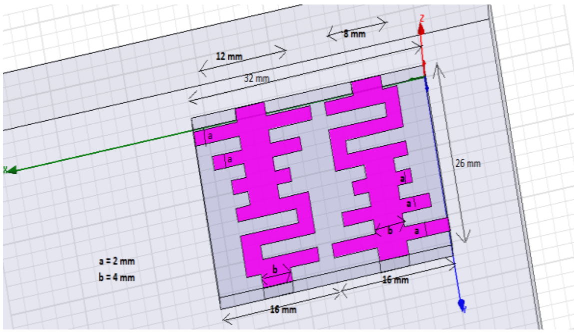

Figure 2: Top View of Cross Couple LineDirectional Coupler for Design1.

The dimensions of the Cross Couple Line directional coupler are states as-x-axis is of 32 mm, y-axis is of 26 mm (made up of copper), and the thickness of the substrate is 1.6 mm three lines are Cross Couple from both feed line named as 'a' of thickness of 2 mm, the dimension of three Cross Couple Line on both feed is 16 mm 12 mm and 8 mm respectively, thickness of feed line is represented by 'b', (made up of copper of PEC in HFSS software) as shown in figure 2.

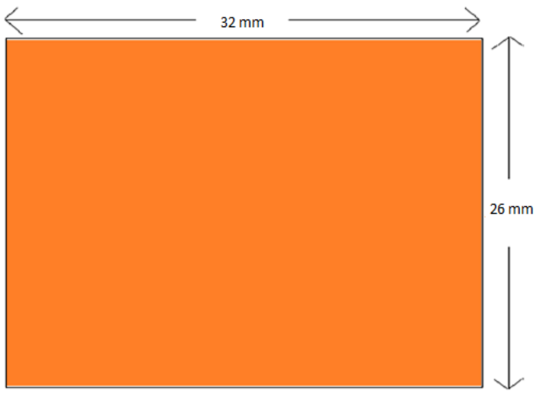

Figure 3: Ground of design 1.

The dielectric material used as substrate is FR4 with dielectric constant ε_r= 4.4. The bottom view of substrate, is shown in Figure 3.

The feeding line is made up of rectangular section which is connected to the different suspended lines the overall dimension of proposed directional coupler is 32 mm × 26 mm stated above.

2nd Design of Reduced Cross Coupled Line DirectionalCouplerModel.

In the 2nd design the overall dimension is same as that of the 1st design 32 mm x 26 mm, rest of the design like feed line is having the dimension of 4 mm by 26 mm. Here we use Reduced Cross Coupled Line of dimension 16 mm, 12 mm and 8 mm for only one feed line with a gap of 2 mm on each of them as shown in Figure 4.

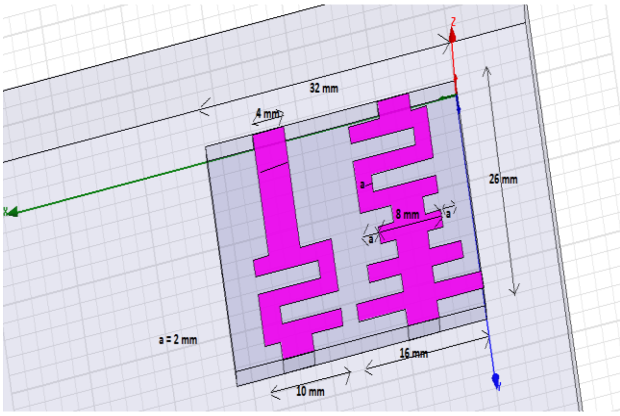

Figure 4: Top view of the 2nd Design of Reduced Cross Coupled Line DirectionalCouplerModel.

V. RESULTS

The simulation result carried out on HFSS software for the different proposed directional couplers are presented in this section.

Table 1: Simulation Result of 1st Proposed Cross Couple Line Directional Coupler.

Radiating Frequency (GHz)	Return Loss S11 (In dB)	Insertion Loss (S21)	Bandwidth (MHz)	VSWR	Coupling parameters S31 (dB)	Isolation parameters S41 (dB)
0.1	-22.32	-0.97	500	1.16	-47.52	-46.56
3.6	-22.75	-0.73	400	1.15	-25.34	-33.21

The table 1 shows the return loss graph generated from the simulation of 1st proposed design. In this design we got bandwidth of 500 MHz and 400 MHz respectively, hence we have also calculated various performance parameter for two center frequency i.e at 0.1 GHz and 3.6 GHz. At this point, we found that the design 1 has insertion loss of -0.97.

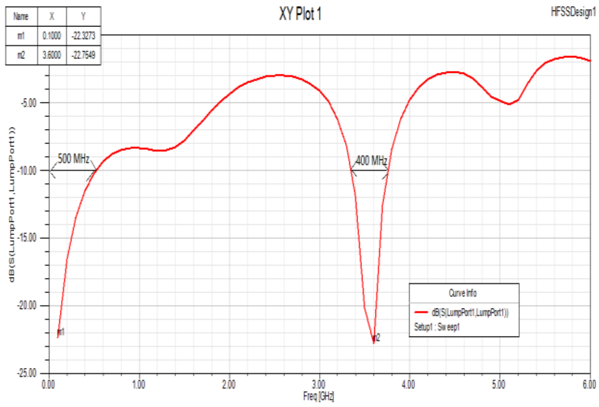

Figure 5: Return loss of simulation result for Design 1.

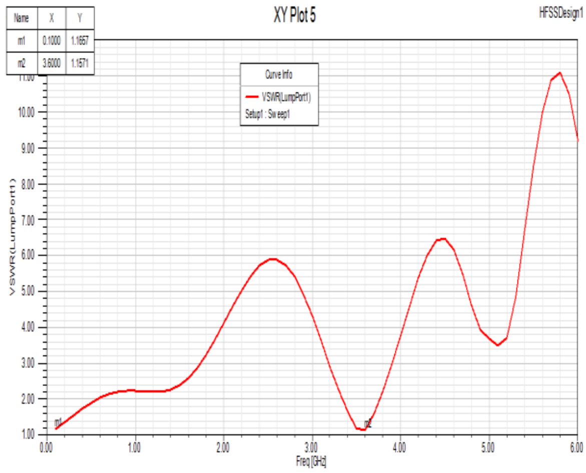

Figure 6: VSWR in dB of simulation result for Design 1 at Port 1.

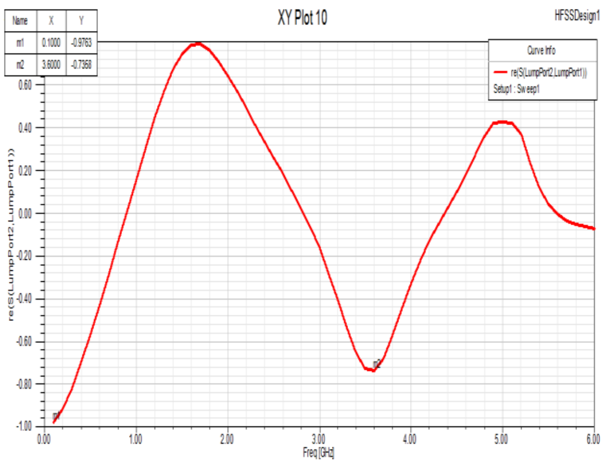

Figure 7: Insertion Loss of simulation result for Design 1

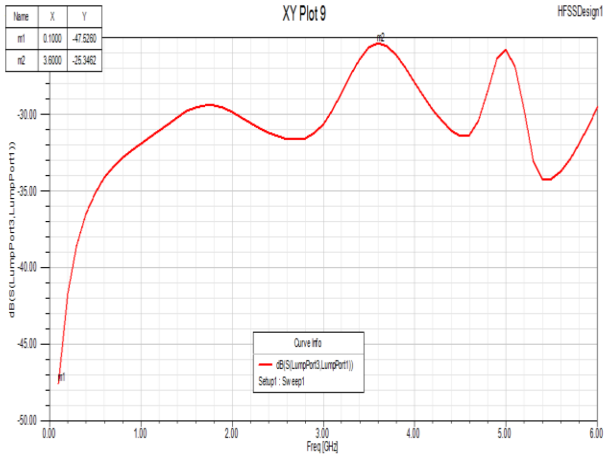

Figure 8: Coupling Factor Coefficient $S_{31}$of simulation result for Design 1.

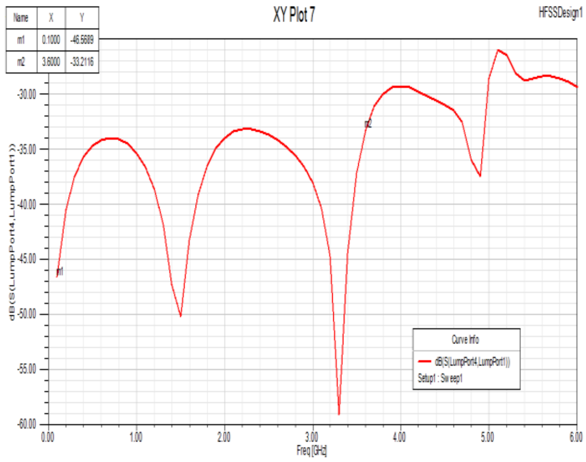

Figure 9: Isolation Coefficient $S_{41}$of simulation result for Design 1.

Table 2 Simulation Result of 2nd Design of Reduced Cross Coupled Line Directional Coupler Model.

Radiating Frequency (GHz)	Return Loss S11 (In dB)	Insertion Loss (S21)	Bandwidth (MHz)	VSWR	Coupling parameters S31 (dB)	Isolation parameters S41 (dB)
1.6	-28.19	0.72	2200	1.08	-32.33	-43.34
5.3	-23.89	0.48	500	1.13	-35.84	-35.42

The table 2 shows the return loss graph generated from the simulation of 2nd proposed design. In this design we obtain bandwidth of 2200 MHz and 500 MHz at 1.6 GHz and 5.3 GHz respectively, hence we calculate the various performance parameter at these point, we found that the design 2 has best insertion loss of 0.72 at 1.6 GHz frequency. The minimum return loss is achieved at frequency of 1.6 GHz and its value is -28.19 dB as shown in the figure 10.

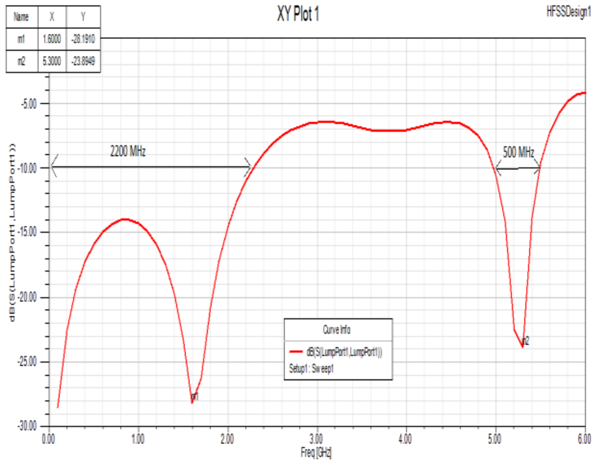

Figure 10: Return loss of simulation result for Design 2

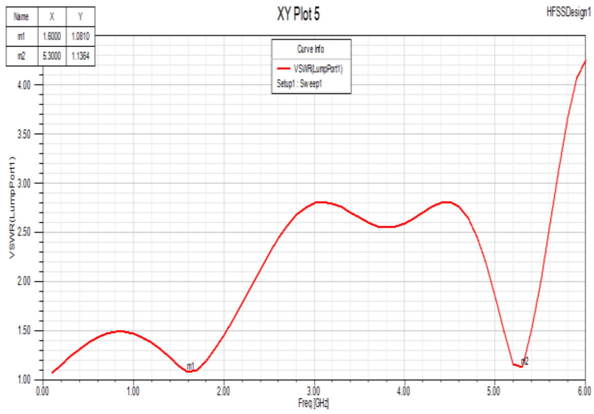

Figure 11: VSWR of simulation resultof 2nd Design at Port 1

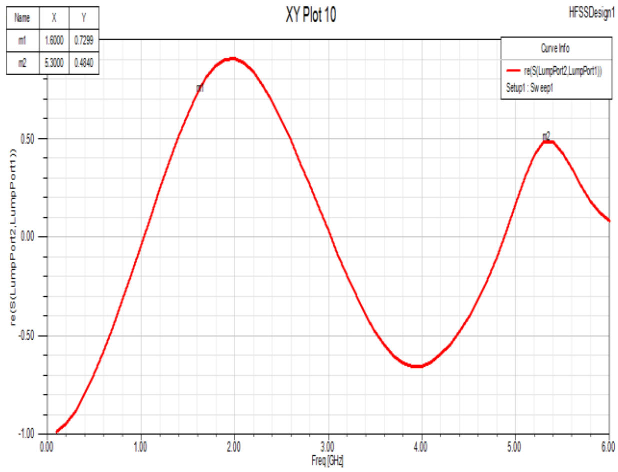

Figure 12: Insertion Loss of simulation result for Design 2.

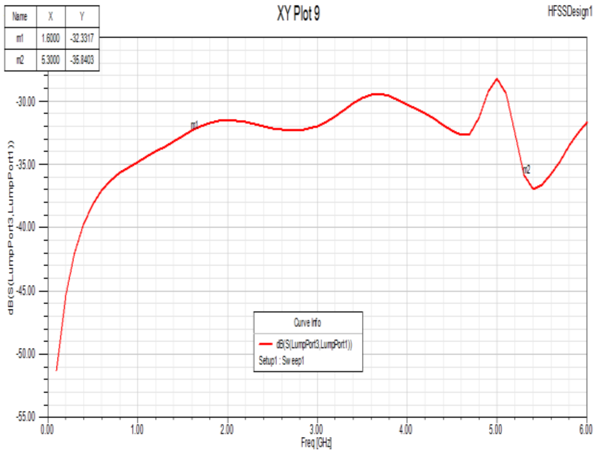

Figure 13: Coupling Factor Coefficient $S_{31}$of simulation result for Design 2

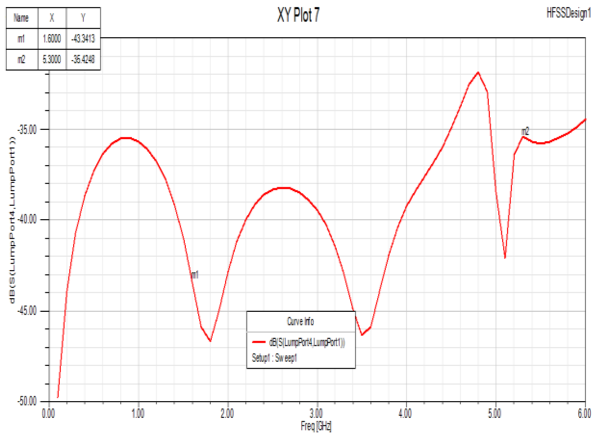

Figure 14: Isolation Coefficient $S_{41}$of simulation result for Design 2.

Table 3: 3rdDesign Hybrid Line Directional Coupler.

Radiating Frequency (GHz)	Return Loss S11 (In dB)	Insertion Loss (S21)	Bandwidth (MHz)	VSWR	Coupling parameters S31 (dB)	Isolation parameters S41 (dB)
1.6	-28.19	0.72	2283	1.05	-31.74	-36.76
5.3	-23.89	0.43	510	1.08	-20.17	-26.75

The table 3 shows the return loss graph generated from the simulation of 3rd proposed design. In this design we get dual band of operation with a bandwidth of 2283 MHz and 510MHz at 1.6 and 5.3 GHz respectively, hence we calculate the various performance parameter at these points, design 3 has insertion loss of 0.72 at 1.6 GHz. The minimum return loss is achieved at frequency of 1.6 GHz and its value is -28.19 dB.

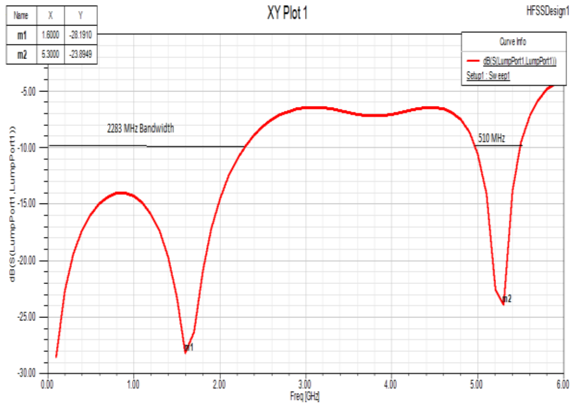

Figure 15:.Return loss for 3rd Design.

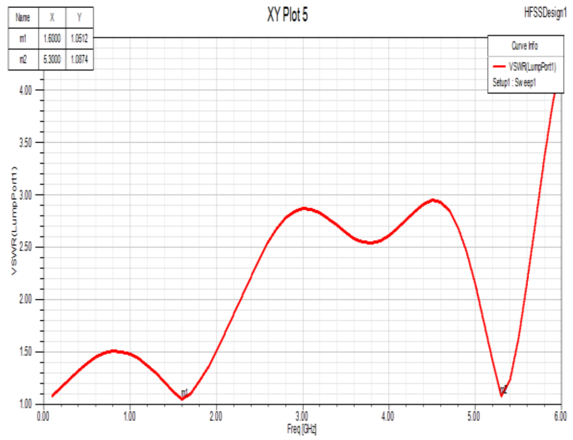

Figure 16: VSWR of simulation result of 3rdDesign hybrid line directional coupler model.

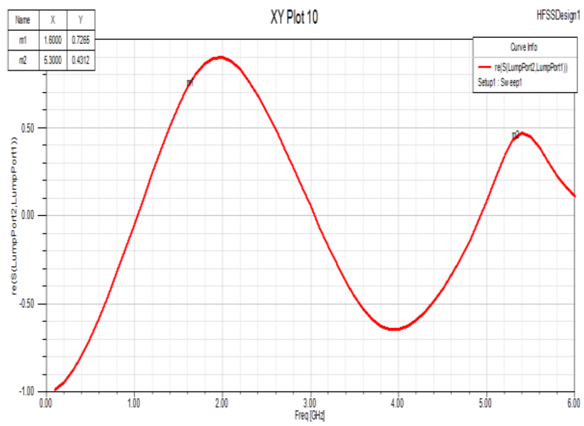

Figure 17: Insertion Loss of simulation result for Design 3.

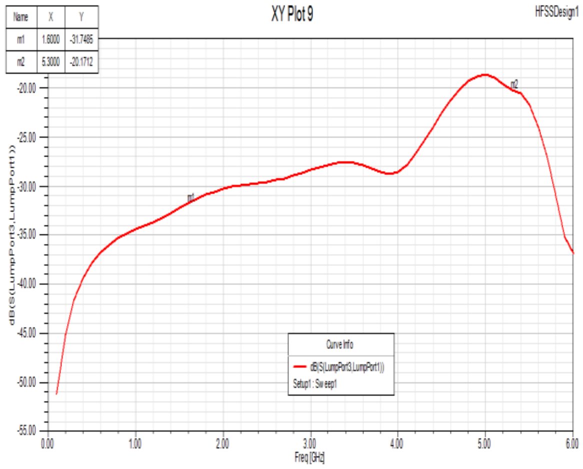

Figure 18: Coupling Factor Coefficient $S_{31}$of simulation result for Design 3.

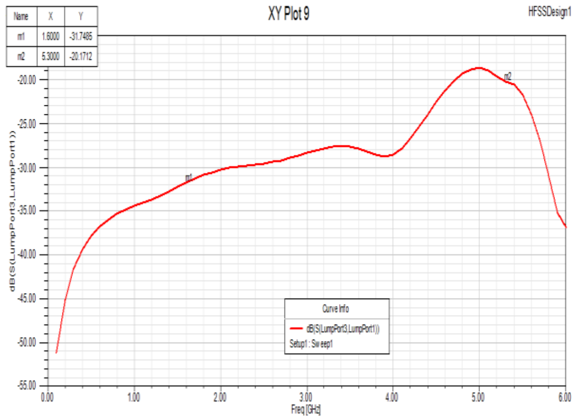

Figure 19: Isolation Coefficient $S_{41}$of simulation result for Design 3.

VI. CONCLUSION AND FUTURE WORK

In this paper the best results are obtained in terms of bandwidth is design 3rd design with satisfactory values of other parameters. In 1st design we have Dual-band of operations with Bandwidth of 500 MHz, and 400 MHz at frequency 0.1 GHz and 3.6 GHz respectively with a return loss of -22.75 dB which is less as compare of other two designs. on the other hand 2nd design has again dual band of operations with Bandwidth of 2200 MHz, and 500 MHz at center frequency 1.6 GHz and 5.3 GHz respectively, with a return loss of -28.19 dB. Thus we can see from the 1st and 2nd proposed design that the introduction of cross couple line increase the S_{31} and S_{41} of coupler on lower range frequency on the other hand reduced cross coupled line increase the bandwidth and return loss drastically, but with satisfactory values of other parameters. Hence we have use a hybrid structure in 3rd proposed design which is based on both cross coupled line and suspended lines. This design will improve the bandwidth even further, Insertion loss and Return loss S_{11} in lower range of proposed. The future design will improve the bandwidth, insertionloss, coupling factor, isolation and return loss in lower range of RFID frequency.

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