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Design and Analysis of Six Port Structure for SDR applications

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Abstract

In this paper, a new topology for six port structures is proposed which can be used in Software Defined Radio (SDR) receivers. This topology is intended to reduce the losses and hardware that are offered by existing topologies. The design of port structure is done using ADS and the performance is analysed using scattering parameters and VSWR values. The port structure in SDR receiver is a direct conversion receiver which down converts the received RF signal directly to baseband signal instead of generating the IF signal as done in heterodyne receivers. Advantage being driving away the problem of image frequencies that occur in IF stage and disadvantage being the added hardware and losses introduced by the port structures. There are few topologies for port structures available now and this work proposes a new topology which can work in the same way as the existing port structure with reduced hardware and losses. The analysis of this design is done using Advanced Design System (ADS) tool. This new design has lesser scattering parameter and VSWR values. These lower scattering parameter values help in reducing the insertion and return losses in the SDR receivers. Also this design has reduced dimensions and so results in lesser area and cost.

Keywords: SDR, port structures, microstrip, power dividers, hybrid couplers, insertion and return losses, scattering parameters, VSWR.

1.Introduction

The history of Software Defined Radios started when J Mitola introduced "Software Radio Architecture" in the year 1995[1], that could process signals of wide range RF and multiple protocols thereby eliminating the problems of the incompatible standards between countries. An extensive work on the SDRs started then and many were attracted towards this technology that rendered great degree of adaptability. In 1995, Renata G Bosisio et al., simulated the SDR receivers[2]. In 1997, Wildmann et al., introduced port structures in SDRs that are capable of eliminating the problems due to IF conversion in conventional receivers [3]. In 2001, Bosisio introduced a novel direct six port receiver[4]. In 2005, Xinyu Xu developed the six port structure based on substrate integrated waveguide technology [5]. In 2011 Karthikeyan et al., proposed five port structures for SDR receivers that proved to be better than the preceding receivers of that kind [6].

SDR receivers being outperforming with the nature of adaptability, had the tradeoffs over area and losses. In other words, the SDR structures occupied more area and incurred more losses. Main challenge in developing SDRs is reducing area and losses. Different technologists arrived at reducing the losses and area by proposing new topologies in the implementation of power dividers [7] and hybrid couplers [9] which are the basic components of the SDR receivers. The intended work now is also to reduce the area and losses further for an SDR receiver

1. Software Define Radio

SDR is a combination of adaptable hardware and the software that decides on the functioning of hardware. Without introducing new hardware, an SDR can modify its properties such as the operating frequency range, modulation type, bandwidth, maximum radiated or conducted output power, and the network protocols by changing the software programs that control the processing resources. This great flexibility of SDR provides a tremendous opportunity for solving interoperability problems between many different existing standards, implementing new standards, and minimizing the amount of hardware necessary to perform required communications across these different standards. SDR allows effective spectrum utilization by facilitating spectrum sharing. It also allows equipment to be reprogrammed to more efficient modulation types. Its capability of being programmed also enhances interoperability between different radio services. The conventional radio systems were having the problems of Image frequency due to the Intermediate Frequency Conversions performed in the mixer units of receivers. These Image frequencies demanded a separate unit for Image Frequency Rejection thereby increasing the cost and size of the receivers. And so we moved to direct conversion receivers those directly converted the RF signals to baseband signals thereby eliminating image frequency problems.

SDR receivers perform this direct down conversion with the help of port structures. Normally six or five port structures are used in SDR receivers.

2. Port Structures

These port structures have one power divider and three or two hybrid couplers depending on the number of ports the structure has. In other words the port structure has two inputs (one from the receiver antenna and the other from the local oscillator) and four outputs (in case of six port structure) and three outputs (in case of five port structure). There are different types of power dividers and hybrid couplers available for use in SDR receivers. These power dividers and hybrid couplers can be implemented using microstrips of FR4 or RT Duroid substrates. The simulation of these components designed using microstrips can be done using ADS software. S-parameter analysis that is supported by ADS simulation allow us to analyse the losses due to these power dividers and hybrid couplers and thereby allow us to modify the design by changing the topology of the system so as to reduce the losses.

1.1Components of port structures

Hybrid couplers, Power Dividers and phase shifters are the major components of port structures. These components are in turn formed of microstrips.

1.1.1. *Microstrips*

Microstrips are transmission lines which can be used for transmitting microwave frequencies [11]. These microstrips have a conducting strip separated from ground plane by a dielectric substrate. Using these microstrips we can form microwave components such as power splitters and couplers. Microstrip devices are built on FR4 substrate that is less expensive. The signal transmitted by a microstrip travels both on substrate and the air and so we need a effective dielectric constant to be specified. That would lie between the dielectric constants of substrate and air. The dielectric constant for FR4 substrate is 4.6

1.1.2. Hybrid couplers

A coupler is a microwave component that allows a part of the signal at one of its port to be available at another port. If the coupling is done in only one direction it is called directional coupler. A directional coupler has four ports.

Port 1 – Input port
Port 2 – Transmitted Port
Port 3 – Coupled Port
Port 4 – Isolated port

A part of power of signal provided at port 1 is given to the coupled port depending on the coupling factor of the coupler. Remaining power from input is sent to the transmitted port. Port 4 is usually terminated with matched load. Couplers are four port devices which are loosely coupled i.e., only a portion of the input signal is coupled to the coupled port. If the coupling factor is 3dB then the directional coupler is called hybrid coupler. If coupling factor is beyond 3db, the power at the coupled port will be more than that available at transmitted port. Then we may need to interchange the name of the ports.

1.1.3. Power Dividers

Power dividers split the input signal power into two parts either equally or unequally depending on the dimensions of the components used. Simple T-junctions can be used as power dividers.

1.1.4. Phase shifters

Phase shifters with required phase values can be selected so as to generate different phase components of incident waveforms.

2. Proposed port Structure Topology

A new topology for the port structure in SDR receiver is proposed in this paper. This topology has two power dividers, two hybrid couplers and two phase shifters. Fig 1. shows such a six port structure.

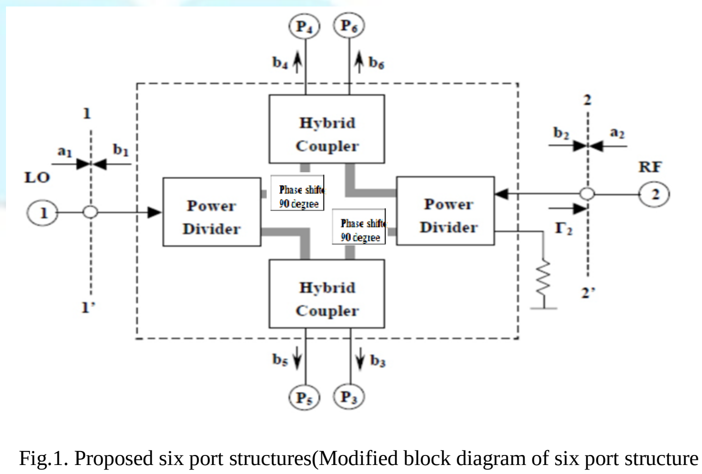

Fig.1. Proposed six port structures(Modified block diagram of six port structure proposed by Xinyu Xu[10])

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The RF input is provided to one of the first power divider, which splits the signal. Similarly the LO input is provided to the second power divider which splits the LO signal. One output of each power divider is given to a 90 degree phase shifter. Now we have four different signals.

- Half Power LO
- Half Power LO with 90 degree phase shift
- Half Power RF
- Half Power RF with 90 degree phase shift

These are input to hybrid couplers which generate four different combinations of power at the outputs.

- Half Power LO + Half Power RF
- Half Power LO + Half Power RF and 90 degree phase shift
- Half Power LO with 90 degree phase shift + Half Power LO
- Half Power LO with 90 degree phase shift + Half Power RF with 90 degree phase shift

This topology takes two different inputs and generate four outputs, it forms a six port structure that can be used as direct conversion receivers. The design of this system is done using ADS tool as on the fig. 2.

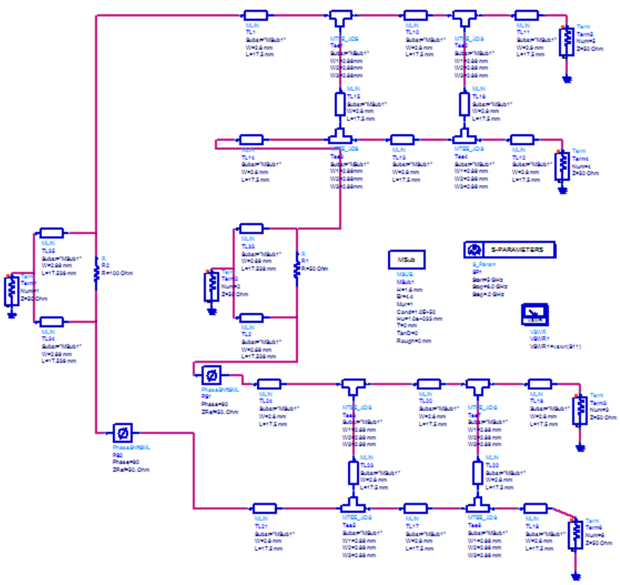
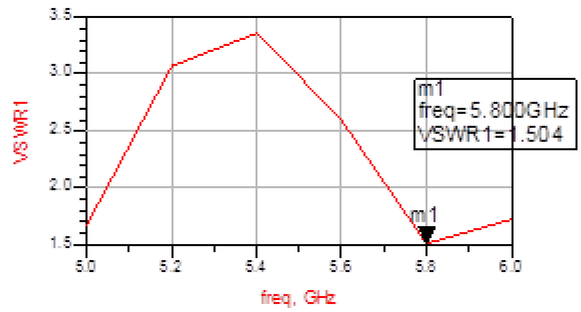
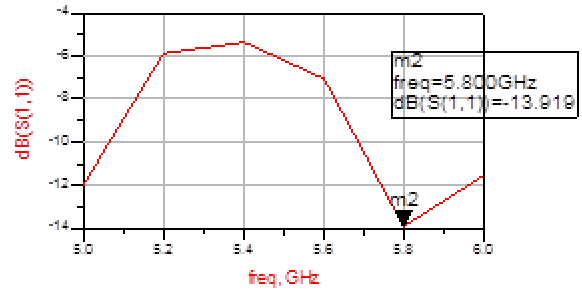


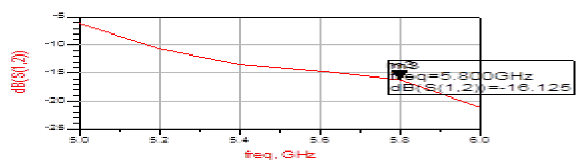
Fig.2. ADS design of six port structure

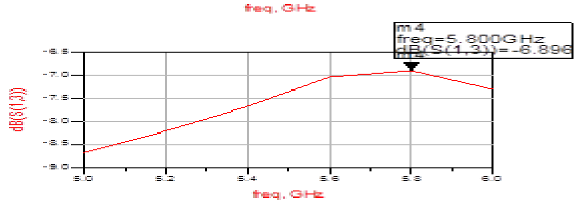
3. Analysis and Results

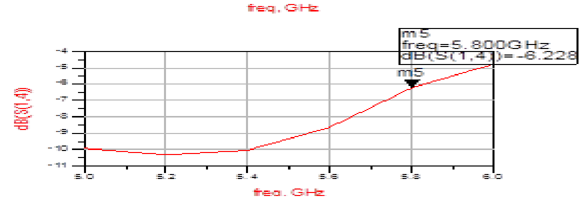
The analysis of the design is done with the s-parameter analysis option available in the ADS tool. The design is made for a 5.8 GHz system. The results are as follows.











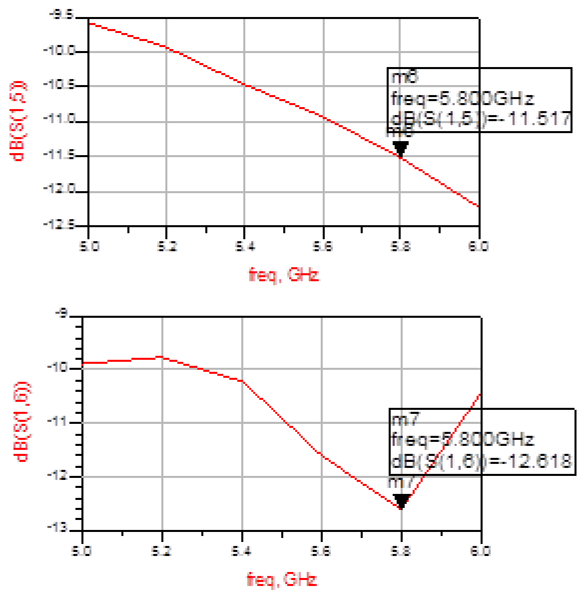


Fig.3. S-parameter and VSWR results

These values allow to calculate the return losses and mismatch losses incurred in the system.

4.Summary and Conclusion

The tabulation of s-parameters is done on table.1.

Table 1

s-parameters	Proposed 6 port design in dB
s11	-13.919
s12	-16.125
s13	-6.896
s14	-6.228
s15	-11.517
s16	-12.618
VSWR	1.502(no unit)

This new topology provides a VSWR value of 1.504 which is lesser than those got in previous designs meaning that the standing waves are reduced which is due to reduced reflections. The reflection loss is calculated to be -13.9dB which is lesser than those obtained in reference papers. The microstrips have the property of radiation which results in radiation losses. The design has reduced number of microstrips (28 microstrips) in this design and so the radiation losses are also reduced.

As proposed the new topology proves to have lesser losses and hardware when compared to designs proposed earlier [8]. Thus the new topology for six port structures is designed using ADS tool and the s-parameter analysis is done and proved that the proposed topology has lesser losses and area compared to the other designs.

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