Implementation of Multi channel-Multi mode Wireless Digital SDR receiver based on Integrated Six Port Technology

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Abstract: **This thesis presents a Software Defined Radio (SDR) which proves a great solution to develop a radio communication process through software. The greatest advantage of SDR is it avoids the hardware and replaces with the software which provides great flexibility to decode all different types of radio signal. Here we proposes a new six-port integrated waveguide structure and our simulation results proves a great flexibility and robustness in system configuration and software reuse of data processing by using quadrature shift keying and 16 quadrature amplitude modulation schemes. This paper presents a universal demodulator for several wireless communications.**

Index Terms—Digital receiver, quadrature amplitude phaseshift keying (QPSK), six-port junction, 16 quadrature amplitude modulation (QAM16), software-defined radio (SDR), substrate integrated waveguide (SIW).

I. Introduction

With the rapid development in the means and ways by which people are required to communicate needs modifying radio devices easily and cost effectively has become business complex. Software defined radio (SDR) technology brings the cost efficiency, flexibility and power to drive communications forward, with reaching benefits realized by service providers and product developers through to end users. In other hand traditional communication systems need complex hardware components like detector, filter and demodulator which leads to high cost. Here we propose a software based radio which makes to implement a radio communication system which is processed simply with software. This SDR system replaces the hardware with the software and it provides a great flexibility to decode all the signals and software reuse.

Simply Software Defined Radio is defined as

"Radio in which some or all of the physical layer functions are software defined".

Classical radio devices are modified through physical intervention only which causes for higher production costs and very minimal efficiency and flexibility in supporting several standards of waveforms. In this paper using the concept of Software Defined Radio provides inexpensive solution for this problem allowing multi functional, multi mode and multi band wireless devices that can be enhanced using software upgrades.

The greatest advantage of proposed SDR is it provides a tremendous opportunity for solving interoperability issues among several radio communication standards software defined radio provides efficient reuse of spectrum by allowing the sharing the spectrum and allowing hardware to be reprogrammed to more efficient modulation types.

Remaining of this paper organised as Section I described about Software Defined Radio with versatility conditions and including SDR receiver architecture. Section II consists of Six port receiver and analysis of six port requirements and technological concepts. Section III describes about six port receiver algorithm and finally Section IV consists of Simulation results using MATLAB.

II. Software Defined Radio

The versatility of software-defined radio:

Traditional radio chips are hard-wired to communicate using one specific protocol. For example, a typical cell phone has several different chips to handle a variety of radio communications: one to talk to cell phone towers, another to contact WiFi base stations, a third to receive GPS signals, and a fourth to communicate with Bluetooth devices. In contrast, software-defined radio hardware works with raw electromagnetic signals, relying on software to implement specifiapplications[17].

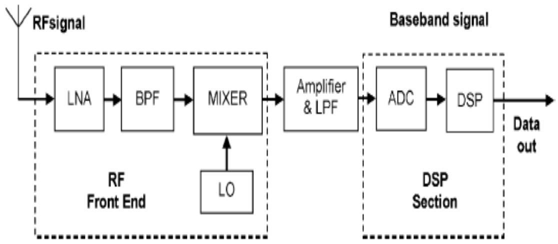


Fig. 1. Block diagram of typical SDR receiver.

Above figure 1 displays the schematic diagram for practical SDR receiver. Initially the input Radio Frequency[2] signals are digitised using samplers after down conversion of the input RF signals. Then the binarised RF signals are sent to DSP, and all of the subsequent processing is implemented in software.

When compared to the traditional radio communication system hardware components[8] SDR system consists of adaptable hardware components which are coexisting with the software drivers that govern the hardware behaviour. The most important operations that are done by SDR[15] are encryption and decryption, spreading and dispreading of frequency spectrum, coding and decoding of multiple access schemes[13].

Architecture of SDR Receiver:

For tuning the desired signal to a baseband or intermediate frequency bands it uses variable frequency oscillator, mixer and a filter. The base band signal is then sampled using the ADC. Generally practical analog to digital Converters lost the dynamic range to pick up nano - watt power and sub microvolt radio signals. Therefore, a low-noise amplifier[11] must precede the conversion step. For example, if spurious signals are present (which is typical), these compete with the desired signals within the amplifier's dynamic range. They may introduce distortion in the desired signals, or may block them completely. The standard solution is to put band-pass filters between the antenna and the amplifier, but these reduce the radio's flexibility. Real software radios often have two or three analog channel filters with different bandwidths that are switched in and out.

The important aspect of reducing the cost is using a six-port receiver. A WDC (Wideband down Converter) is not available at millimetre wave frequency level. So a six port receiver will work as wideband down converter. Six port junctions[10] with the combination of power detector will work as radio frequency signal down converter to baseband level. By converting the RF signal into low frequency baseband signal[1] it reduces the analog to digital converters sampling and digital signal processing capability requirements.

III. Six Port Receiver

In the implementation of Software Defined Radios Six port receiver is a very interesting and emerging radio frequency implementation. The main feature of six port receiver is it provides large BW[5] and involves multi mode and multi band capabilities.

THE SIX-PORT THEORY:

Additive Mixing

In conventional multiplicative mixer the input signals are added and subsequently squared. The non linear element is used to for squaring purpose.

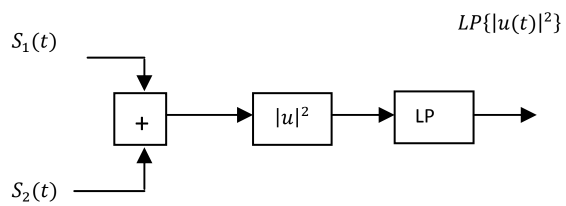


Fig. 2.Principle of additive mixing

S_1(t) is the oscillator signal and defined as

$$S_1(t) = A_{Lo}.\cos(\omega_{LO}t + \varphi\varphi_{LO}) \quad (1)$$

$$S_2(t) = x_{BP}(t) = x_I(t).\cos(\omega t) - x_Q(t)\sin(\omega t) \quad (2)$$

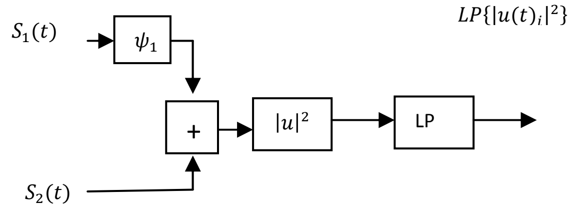
$$x_I(t)\ is\ inphase\ constant$$
$$xQ(t)\ is\ quadrature\ constant$$

The added signal gets squared and low-pass filtered to the baseband bandwidth

$$LP\{|u(t)|^2\} = \frac{1}{2}\left(A_{LO}^2 + x_I(t)^2 + x_Q(t)^2\right) + \cdots + A_{Lo}.\left[x_I(t)\cos(\Delta\omega t + \varphi_{Lo}) - x_Q(t)\sin(\Delta\omega t + \varphi_{Lo})\right] \quad (3)$$

Receiver with Multi-Port:

Assume to create a linear independent power measurements allow phase shifts of ψ_i in one input path, then to measure the complex baseband signal y(t) we require minimum 3 independent paths



$$LP\{|u(t)_i|^2\}$$

$$y(t) = x_I(t) + j.x_Q(t) = \sum_i c_i LP\{|u_i(t)|^2\}$$

c_i: complex calibration coefficient

Assuming that the phase shifts are done by a simple delay line an error ε is introduced by deviating from the design frequency. The initial local oscillator phase ϕ_{LO} , as well as the frequency difference Δω is unknown.

$$\varphi = [0^O, 90^O + \varepsilon, 180^O + 2\varepsilon, 270^O + 3\varepsilon$$

Therefore a multi-port receiver equation is formulated in matrix notation as

$$y(t) = A_{LO}.\begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix}^T . \begin{bmatrix} \cos(\theta(t)) & -\sin(\theta(t)) \\ \sin(\theta(t)+\varepsilon) & \cos(\theta(t)+\varepsilon) \\ -\cos(\theta(t)+2\varepsilon) & -\sin(\theta(t)+2\varepsilon) \\ \sin(\theta(t)+3\varepsilon) & \cos(\theta(t)+3\varepsilon) \end{bmatrix} . \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} \quad (4)$$

Six-Port Realization:

By using 90° hybrid couplers a common mechanism for four independent phase shift is shown in fig4. This coupler consists of local oscillator and RF band[4] pass signal inputs.

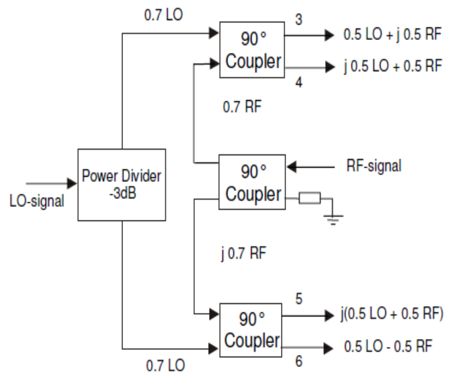


Fig. 4. Realization of a six-port

Below figure 5 is a simple power detector circuit for a low pass filtering to determine the power of each six port output.

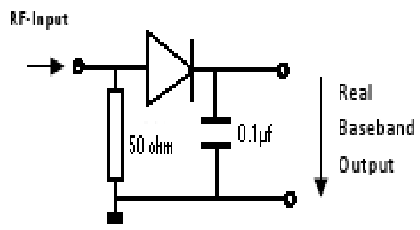


Fig. 5. Simple power detector circuit

The architecture of the six port receiver is categorised as analog and digital part of the frontend. With four different phase conditions the amplified and band pass filtered input signals are added in analog frontend. After corresponding match the measured final signal power is send to analog to digital converter i.e. low pass filtering to the baseband bandwidth and amplification to match the ADC, which feeds the converted data into an FPGA. The FPGA contains the necessary digital signal processing in order to calculate the complex base band signal.

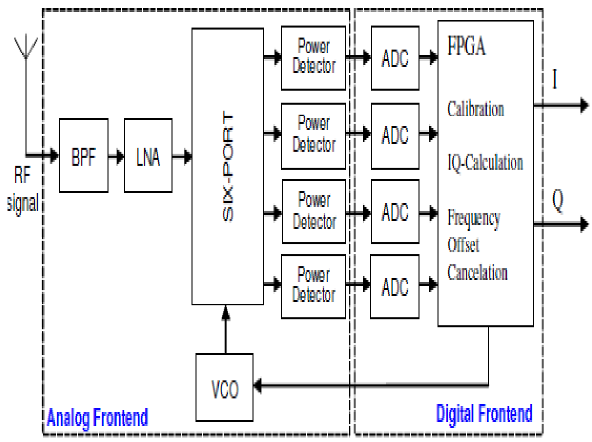


Fig. 6. Six-port receiver architecture

IV. Six Port Receiver Algorithm

Below figure 7 displays the flowchart for SDR Six port receiver[10]. As discussed before here six port calibration samples are generated on ADC converted output. These calibration coefficients are used to compute the in phase and quadrature data.

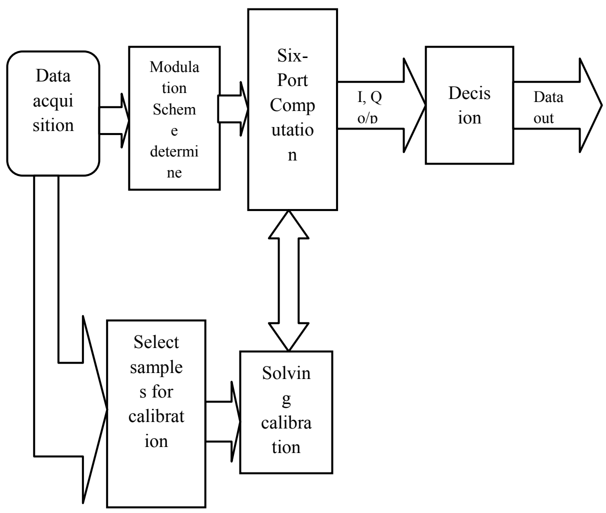


Fig.7. Flowchart of six-port receiver algorithm.

And finally a demodulation algorithm is used to demodulate the signal based on concept of decision making. This is the universal demodulation algorithm for six port receivers. In the proposed receiver platform, a real-time six-port calibration method [14] is adopted and the demodulation results for different modulation schemes are analyzed.

V. Simulation Results

Here to test the performance of the proposed SDR scheme two different modulation schemes 16 QAM and QPSK are selected and by using MATLAB simulation scheme we have evaluated the results.

Simulated input and out signals for QPSK and QAM 16 modulations signals are shown in below fig 8.

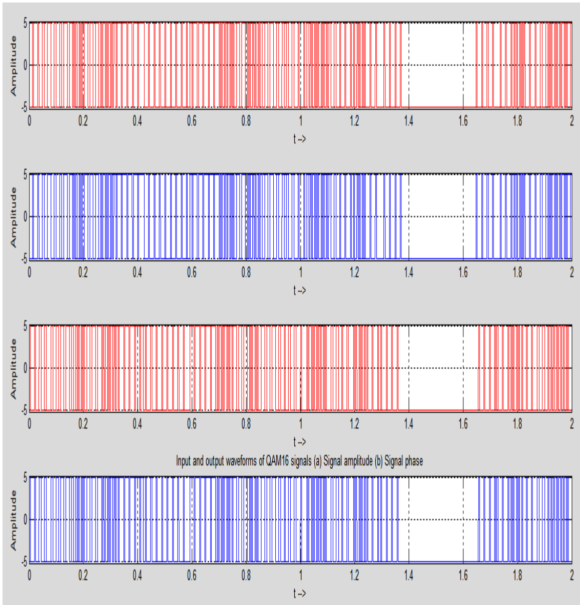


Fig 9: Input and output waveforms of QPSK and QAM 16signals

In the above simulated results the output bit sequence is the demodulated signal after six port computation and decision. From the above results the input and output signals are approximately same at the operating frequency 1 GHz.

Figs. 10 and Fig 11 show the simulated output signal constellations for QPSK and QAM16 with various signal-to-noise ratios (SNRs).

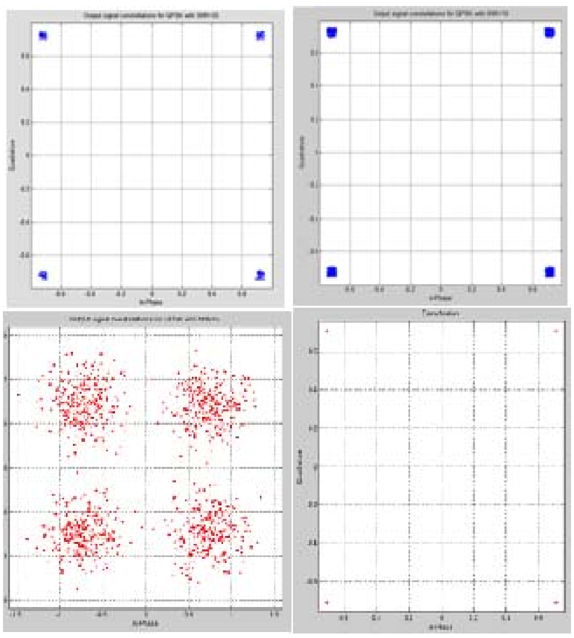


Fig. 10. Simulated output signal constellations for QPSK with different SNR.

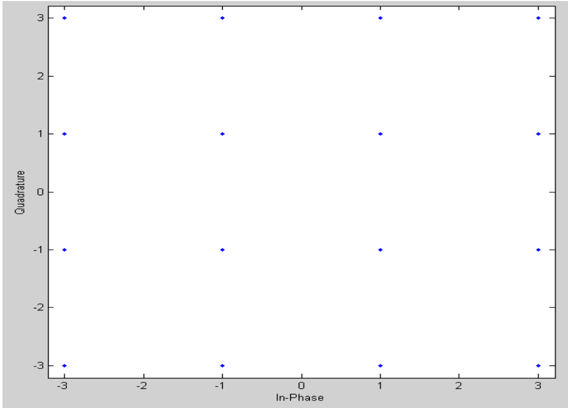


Fig. 11. Simulated output signal constellations for QAM 16

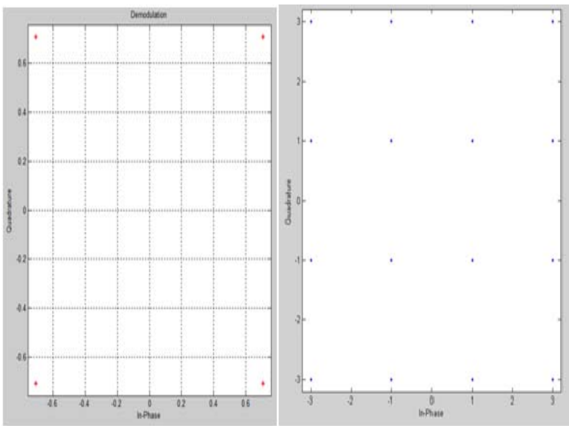


Fig. 12: Six port receiver output signal for QPSK and QAM 16

Above figure consists of demodulation results for QPSK and QAM 16 schemes and it has found that the output constellations is definitely stable and the signal is exactly demodulated if the SNR has the acceptable value.

Measured and Simulated Bit Error Rate[6] for the two modulation schemes are presented in Figs. 13 and 14, where is the average energy of a modulated bit and is the noise power spectral density[16]. The QPSK and QAM16 signals are generated from a vector modulator without coding.

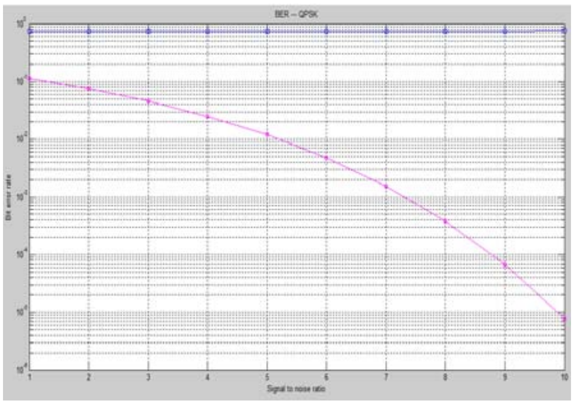


Fig. 13. Simulated BER for QPSK.

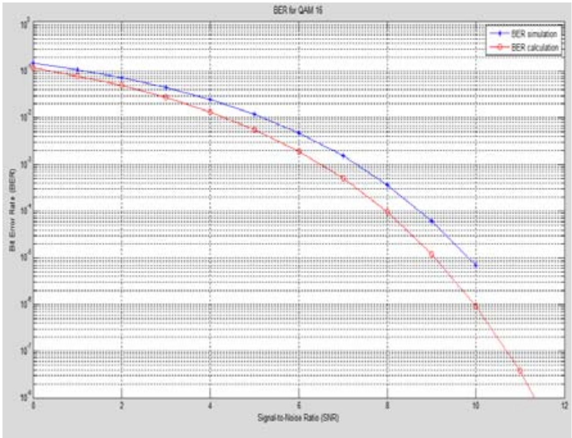


Fig. 14. Simulated BER for QAM16.

VI. CONCLUSION

A SDR Receiver with Six port platform has been proposed, analyzed and implemented in this thesis and the very recent analyzed the results in a six port receiver for multimode RF signal communications. This platform adopts a new SIW six-port structure at the RF front-end, which realizes wideband direct down conversion for low-cost and mass-producible SDR applications based on six-port front-end, the demodulation algorithms.

In this paper we have analyzed the Bit Error Rate and demodulation performance of the Software Defined Radio for QPSK and QAM16 Modulation Schemes. Finally the simulation results are concluded for possible universal receiver solution for future software-defined radio applications in various wireless communication systems.

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