Zero-IF Active Antenna with I&Q Detection Function

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Abstract

An active antenna used for I&Q demodulation is discussed in this paper. Two Schottky diodes are integrated with the patch antennas to function mixers. The advantages of this architecture are simple circuitry, low power consumption, natural rejection for the image frequencies and cheaper cost in manufacture.

Introduction:

At present the majority of radio receivers adopt the superheterodyne technique which can provide high selectivity and sensitivity. In a superheterodyne system, a narrow band-pass filter follows a down-conversion mixer and the signal is amplified at different stages, RF (Radio Frequency), IF (Intermediate Frequency) and baseband. The system has many advantages, such as good stability, high gain, low noise and flexibility for channel selection. In order to reject the image frequency, the IF frequency is generally set to 70-300MHz in most mobile receivers. Amplification in such a high IF frequency will require a large current from the power supply. Further, the lossy passive IF filter may be difficult to integrate with other components on a MMIC chip. Thus, the superheterodyne technique also encompasses some difficulties, especially when the demands for low power consumption, simple circuitry, low cost and compact size need to be satisfied.

The Zero-IF (ZIF) or homodyne detection principle was proposed in late-1940s.[1] This technique was used in some practical systems, for example, microwave measurement and radio-paging receivers. Besides the strengths of simply architecture, low power consumption and cheaper cost of manufacture, ZIF detection has immunity to the image frequencies interference, so the preselection RF filter also can be eliminated. As the digital signal processing speed increases and techniques develop, most of the jobs in a receiving system can be accomplished at baseband where isolation, amplification, filtering and control easily implemented. All these factors will probably prompt ZIF technique to be used in new transceiver architecture.

I&Q or Qudrature modulation/demodulation is widely applied to digital mobile communication systems, for example, GSM(Global System for Mobile Communication), DCS1800(Digital Communication System−1800 MHz) and DECT (Digital Enhanced Cordless Telecommunications). The benefit of I&Q detection is both amplitude and phase information to be obtained simultaneously.

In this paper, a ZIF active antenna with I&Q demodulation functions will be described. The design intention is to provide a novel active antenna architecture , which can serve in the digital communication systems. Another application is for direction detection. Although a self-mixing active antenna can measure the Doppler frequency of moving targets, it can't provide any information about the target's direction. [2]

Operation Principle and Configuration

The schematic of the I&Q detection is demonstrated by Fig-1. Assuming the RF signal has I&Q modulation, it can be expressed by.

$$v(t) = \mathrm{Re}\{g(t) * e^{jw_c t}\} \tag{1}$$

Where $g(t) = x(t) + jy(t)$ is the baseband signal and w_c the carrier frequency. The RF signal can also be written as

$$v(t) = x(t)\cos w_c t - y(t)\sin w_c t \tag{2}$$

When the local oscillator(LO) frequency is tuned to the carrier frequency and divided into two branches which have 90° phase difference, the LO and RF signal are mixed to produce different products at two output ports. At the in-phase port

$$\cos w_c t * v(t) = \cos w_c t * \{x(t)\cos w_c t - y(t)\sin w_c t\}$$

$$= \frac{1}{2}\{x(t)(1+\cos 2w_c t) - y(t)\sin 2w_c t\} \tag{3}$$

Similarly, at the quadrature port

$$-\sin w_c t * v(t) = \frac{1}{2}\{x(t)\sin 2w_c t + y(t)(1-\cos 2w_c t)\} \tag{4}$$

The real and imaginary parts of the baseband signal, $x(t), y(t)$ will be output at in-phase and qudrature ports after filtering. From the analyses above, this detection method can provide both amplitude and phase information of the baseband signal.

Following this principle we implemented an active antenna shown in Fig-2. Two Schottky diodes (HSMS-8101, HP) are used as mixers. One pin of the diodes is connected to the edge of the patch and the other pin is grounded via a small hole to ground plane. LO power is divided into two branches by a Wilkinson power divider and 90 ° phase delay is realised by different lengths of microstrip lines. A capacitors is used for a high pass filter at each patch, so that the LO power can pass through and the baseband signals are blocked. The inductors form RF chokes. The two patch antennas operating at 1.88GHz function both as a receiver to pick up RF signal and also as a part of the I&Q demodulator circuit. The Schottky diodes only need a very low biasing voltage of about 0.25V.

Experiment Result:

1) I&Q detection

The experiment is carried out as demonstrated in Fig-3. A commercial I&Q modulator (MIQC-1880D, Mini-Circuits) is used. The modulator has three input ports, one for the carrier (1.88GHz, 5dBm) and two for the I and Q signals in baseband (1MHz, 0dBm). The I&Q modulated signal is output to a transmitting antenna after amplification(30dB). Simultaneously, the carrier signal is input to the active antenna to act as local oscillator. The distance between the transmitting and receiving antennas is 0.8m. Because the LO and carrier of the modulation signal are at the same frequency, the Zero-IF frequency will be produced after mixing the RF and LO. I and Q signals of -52dBm are detected shown in Fig-4 and Fig-5.

2) Direction detection

Another function of the antenna is to detect incoming wave direction. When the transmitting antenna is not put the broadside on to the active antenna, the phase difference at two ports is not 90 °. As the antenna moves towards the I port, the phase difference of the two signals decreases. When the antenna moves towards the Q port , the phase difference increases. Thus, by the phase difference, the direction of transmitting antenna can be determined. Fig-6 and Fig-7 demonstrate the phase variation as the incident wave direction changes.

Conclusion

The active antenna with I&Q demodulation and direction detection functions shows the potential to apply for the practical communication and radar system. The novel architecture has the advantages of simple circuitry, low power consumption and cheaper manufacturing cost.

References:

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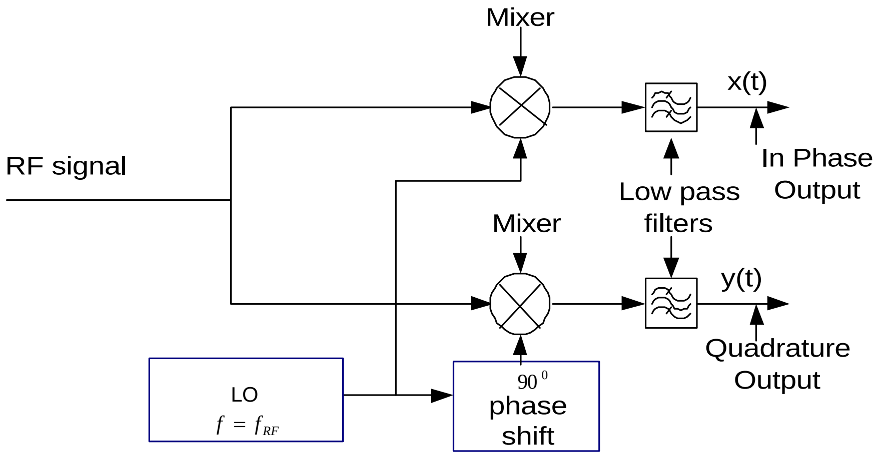

Fig-1, I&Q demodulation schematic

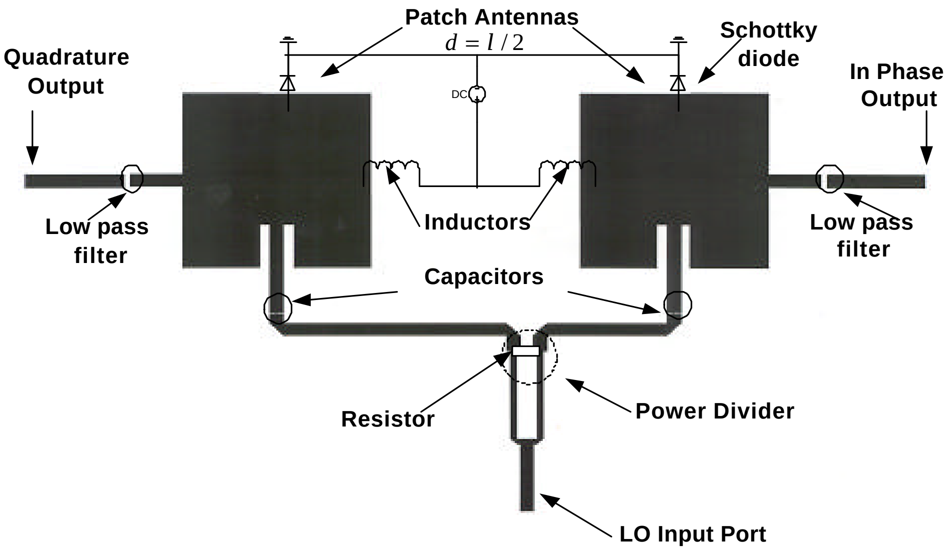

Fig-2, Active antenna layout

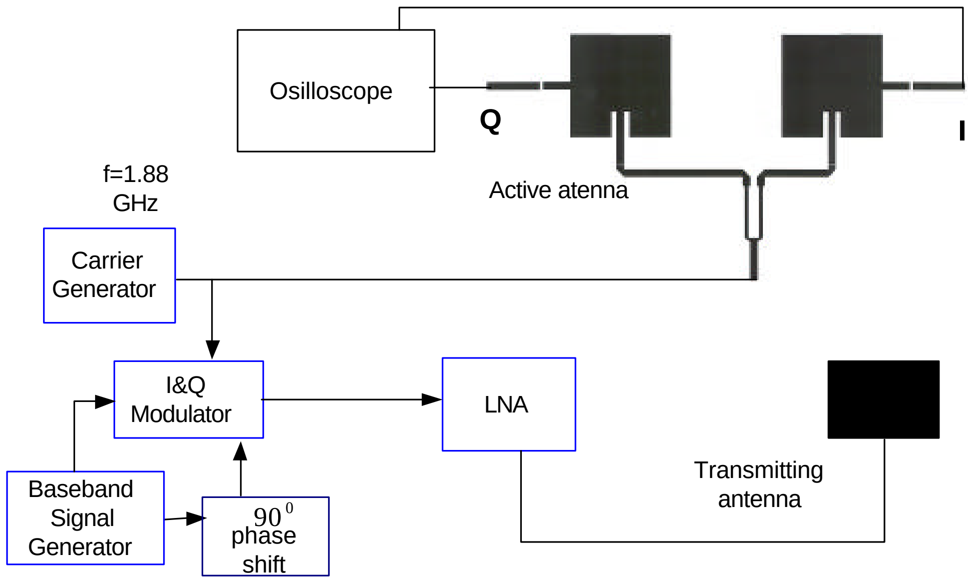

Fig-3, Experiment arrangement

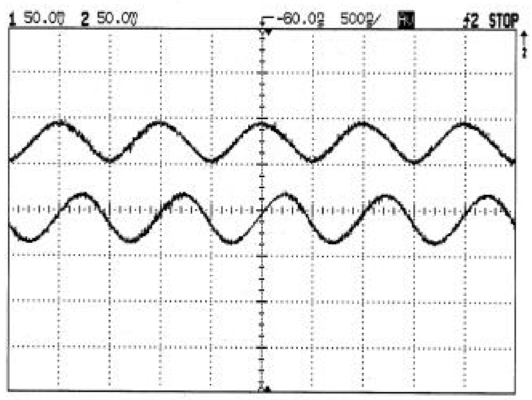

Fig-4, I and Q signal detected by active antenna

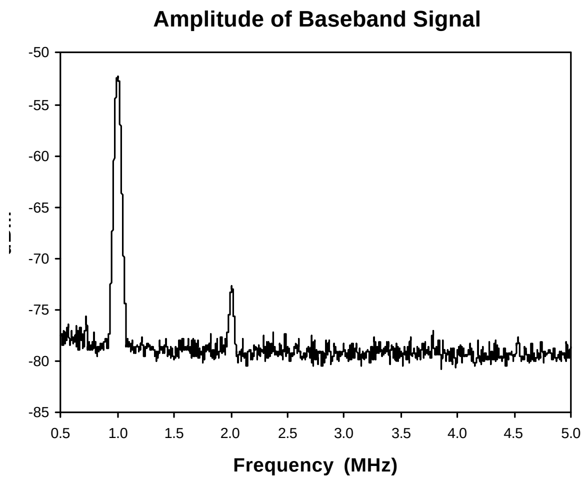

Fig-5, Baseband signal amplitude

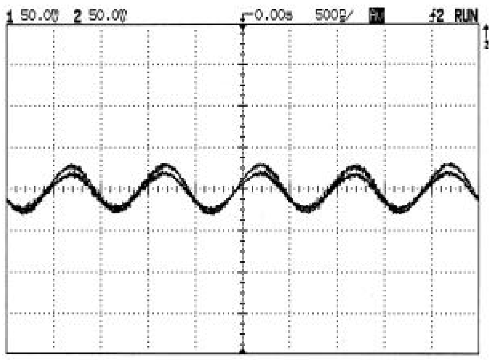

Fig-6, 0 ° phase difference as transmitting antenna offsets 60°off the broadside

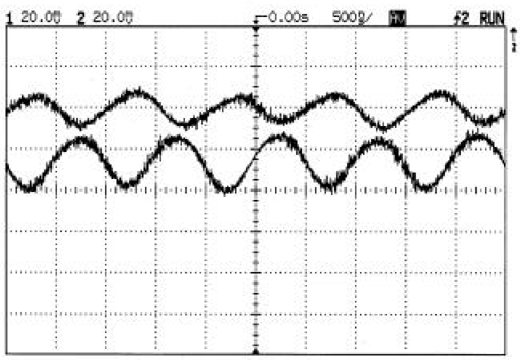

Fig-7, 180 ° phase difference as transmitting antenna offsets 150°off the broadside