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UHF RF Transmitter and Receiver

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ABSTRACT: Here we propose a current mode oscillator circuit using Q-Dot technology and subsequently we modify this circuit for transmitter and receiver design. We like to note that transmitter is a amplitude modulation (AM) to frequency modulation (FM) conversion technique. The receiver is of Super heterodyne structure, where the RF front end is implemented by Q-Dot devices and the IF stages are implemented by HEMT/CMOS devices.

1.0 INTRODUCTION

Strong demand for micro miniaturized integrated wireless RF circuit [3] and growing market for higher spectrum have forced researchers to look for new nano technology other than CMOS, BJT, HEMT devices. In this paper we introduce Q-Dot devices for making an oscillator working at 5-15 GHz frequency. This circuit uses current mode charging and discharging of capacitors in back to back fashion in millivolt range.

Q-Dot technology is touted as the next generation computer device [1][2]. Here we try to use the technology for solving analog circuit problem such as UHF RF mixers. For high frequency application, we need highest mobility of electron. GaAs heterostructure can make electrons have very high mobility at low temperature. It was reported that any two materials with different lattice constant would result in formation of island. First it was reported by Goldstein in 1985 of InAs islands on GaAs. Now island sizes are of few nanometer and can confine charges. The electronic property of Q-dot is determined by Coulomb repulsion of charges and Coulomb blockade phenomenon.

The Section II describes the model for Q-Dot devices and Section III designs the oscillator circuit. In Section IV this design idea is extended for a transmitter. In the Section V we extend our idea further to super heterodyne receiver structure. Section V explains the front end mixer circuit and Section VI describes the superheterodyne structure. Section VI concludes the paper.

2.0 Q-DOT MODELLING

Single dot Q-dot is a three terminal device and has same terminology as FET devices. They are called source, drain and gate. The electrons move from source to drain through the dot floating over gate. The electron mobility is very high, but because of Coulomb blockade, the electron flow is independent of magnitude of gate voltage, but at some values .

3.0 OSCILLATOR

Two Q-dots can be connected in back to back fashion. The electron charge is taken from a capacitor (C1) so that the voltage across the capacitor will be higher. The charge is given to a capacitor (C2), so that its voltage will be lower.. Now the C1 lid will be connected to the gate voltage of Q-dot2 that is to Vg2 and the lid of C1 will be connected to the gate voltage of Q-dot1 that is to Vg1. Now as Vg2 is higher voltage then Q-dot2 will conduct and voltage across C2 will be higher and voltage across C1 will be lower. So Vg1 will be higher and at some point Q-dot1 will start conducting. This way Q-dot1 and Q-dot2 will conduct one after another. The voltage across the capacitance will pulsate at very high frequency across a bias voltage. The bias voltage is given from a dc source. At high frequency the lid from dc source behaves like an inductor and so there is no leakage of high frequency ac voltage. The frequency of oscillation depends on the value of capacitor and the current flow in the Q-dots. The oscillator circuit is shown in Figure 1.

4.0 TRANSMITTER

The transmitter is as shown in Figure 2. Here an oscillator is oscillating at a center frequency fc and HEMT current source will subtract current from Q-dot circuit. Let us assume that the current in Q-dot is I_1 and the current in HEMT current source is □ I_2. So the total current passing to the capacitor will be I_1-□ I_2. The frequency will calculated as

$$V_x = \frac{1}{C}\int_0^{\delta T_1}(I_1 - \delta I_2)dt$$

The time □ T_1 is such that V_x reaches V_{x1} and the frequency is given by $1/(2*\pi*2*\delta T_1)$. So the frequency will be fc+/-fm, where fm is the modulating signal at the base of the HEMT devices.

Now, $V_{x1}=\delta T_1*(I_1-\delta I_2)/C$ and $\delta T_1=V_{x1}*C/(I_1-\delta I_2)$, hence it will a Amplitude Modulation to Frequency Modulation.

5.0 MIXER IN THE RECEIVER

Mixers in the receiver are of two types. Type I mixer is for lower RF frequency demodulation. It is similar in structure to the mixer in the transmitter. Here the RF signal is in the base of HEMT device and it modulates the current through the oscillator. The oscillator has a frequency (fo) slightly different from the incoming RF center frequency (fc). The output frequency (fc-fo+/-fm) will be fed to the Intermediate Frequency stage. It is shown in Figure 3.

In the type II mixer, the RF signal is added to the oscillator frequency. Then it is passed through a low pass filter and then through an envelope detector. Following the envelope detector is the Intermediate frequency stage. Because of nonlinear signal processing, this kind of demodulator is good for FSK transmission. The mixer is shown in Figure 4.

6.0 SUPERHETERODYNE STRUCTURE

Normally, if the RF frequency is in the range of UHF, then intermediate stage of mixing is used. Now to choose the frequency, we need Band pass filter at RF frequency, which is almost impossible to design. In direct down conversion, we put a low pass filter of bandwidth fm to get the desired signal and get rid of the out of band signals. But, designing a VCO at RF frequency with a frequency variation is difficult. In two stages down conversion, we have to reject the image frequency. We can use double mixing of signals and adding them with phase delay of p/2 to get rid of the unwanted signal. Figure 5 and 6 show these super heterodyne structures. The demodulator is a FM detector to detect FSK signal. We prefer to use a zero crossing detector to demodulate which is not shown here.

7.0 CONCLUSION

Here we proposed to implement analog circuits using Q-dot devices. We used an oscillator circuit to implement various mixer circuits. As the oscillator may work in UHF range, the mixers have potential applications in 5-15 GHz range. Other than this application we perceive other applications such as design of voltage controlled oscillator circuits for PLL.

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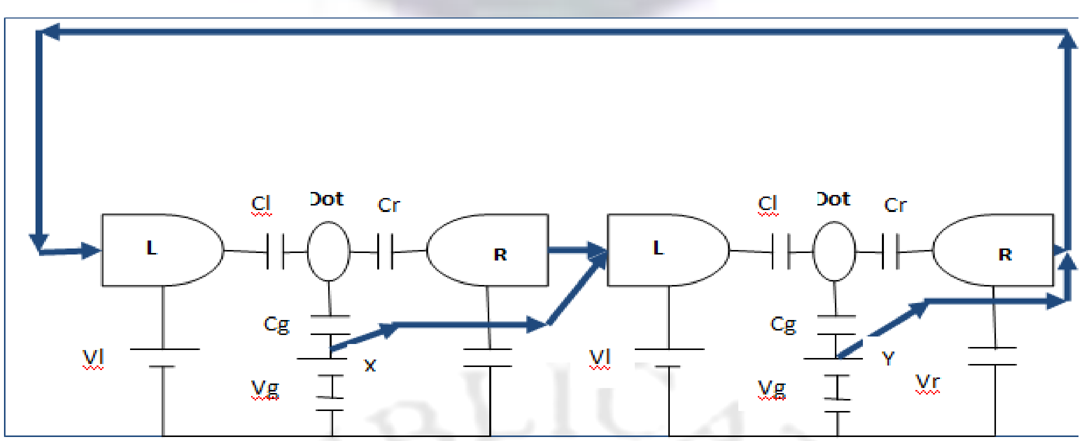

Figure 1. The oscillator circuit.

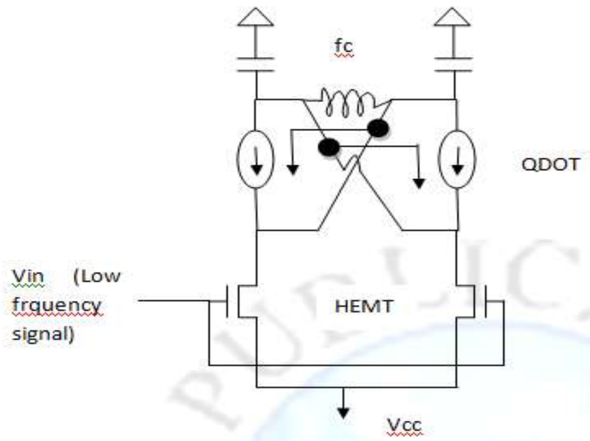

Figure 2. Mixer at transmitter

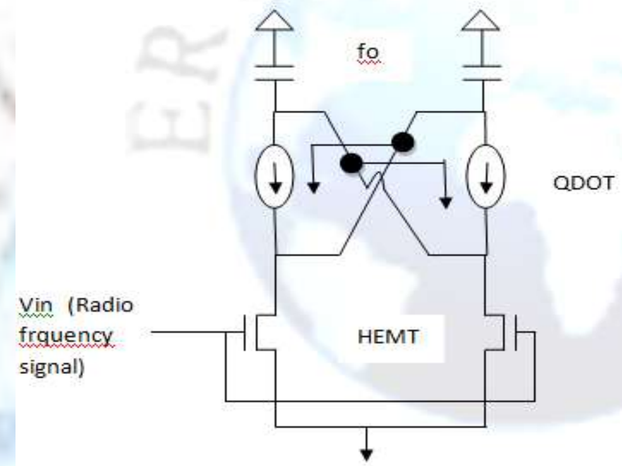

Figure 3. Type I Mixer at Receiver

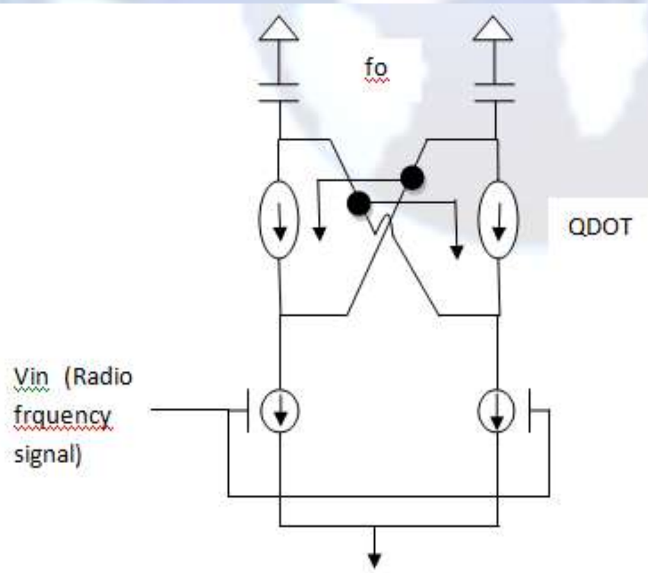

Figure 4 Type II Mixer at receiver

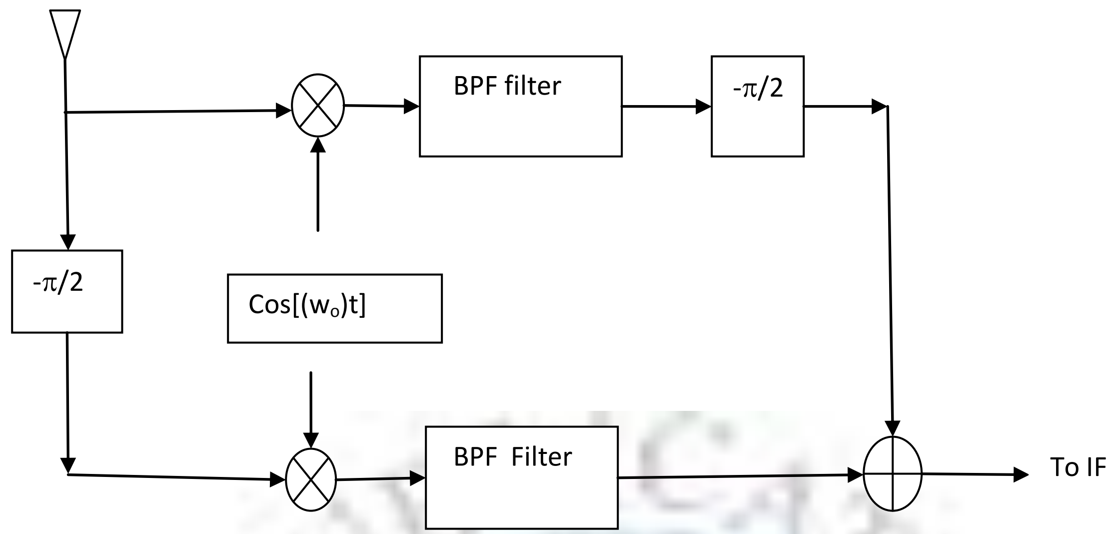

Figure 5. Super heterodyne receiver- RF stage

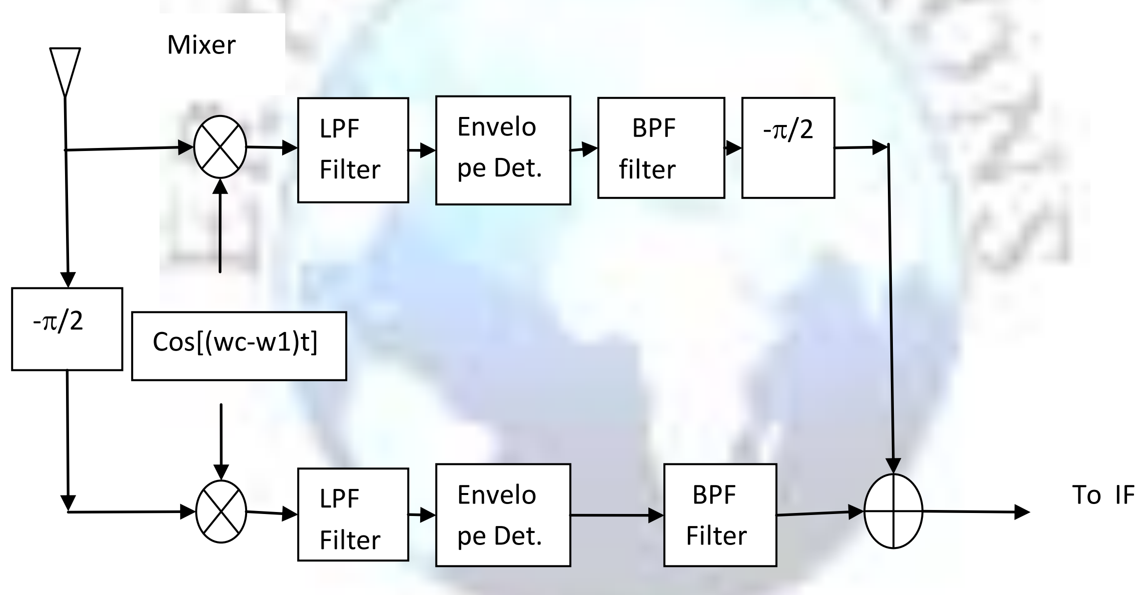

Figure 6. Image rejection in RF super heterodyne structure.