Crystal Notch Filter Design For Detecting Clutter to Low Altitude Radar

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ABSTRACT:
On low altitude radar system heavy reflective clutter from earth case saturation receiver amplifier, for stoppage receiver saturation using a crystal notch filter on input of IF stage Crystal filter having high Q and selective frequency and band width, they have high resistance for changing temperature so this filter suitable for radar receiver. In this paper we try to showing suitable method for increase Q and selective width of filter band width, to design a filter can attenuation 60dB selective band width of receiver by selective frequency. On crystal notch filter using trans for increasing circuit impedance and filter band width.

KEYWORDS: Crystal notch filter, low altitude radar, clutter , filter Q increasing.

1. INTRODUCTION

On low altitude radar systems, due to collision of the waves to the mountains, forests and the sea surface a heavy Clutter is created. Because the power difference between clutter and returned Doppler reaches to 60dB, and since the Heavy clutter has a high power it leads to the saturation of low noise receivers amplifiers. So the heavy clutter by exiting from RF unite (In RF unite cannot be designed narrowband filter) deleting by a Notch filter it has high Q and specified bandwidth (Figure.1. Block diagram of a radar receiver) to prevent saturate of the receiver low noise amplifier because radar receiver system must be able to Doppler power -135dBm discovered. Figure.2. Effects of noise and clutter on radar systems Doppler show. Q Inductors have an impact on the minimum width of LC filters; in order to acquire t a better Q from resonant circuit filtering, Quartz crystal or **PLZ**T ceramic or mechanical resonators, which requires an external limiting are used. A quartz crystal is Piezo electronic device, which has a high Q and good stability at high temperatures in long time and despite of the quartz rigidity it is not fragile. The crystals in a wide band of frequencies from audio to VHF bands are produced. Crystals have different cuts, and each cut can be used for a specific frequency range; for example, the AT cut for the frequency range of HF and VHF, SL and DT ones for lower frequencies Due to frequency stability, resistance to high temperatures and movement of crystal filters they are used in notch filters of radar receivers.

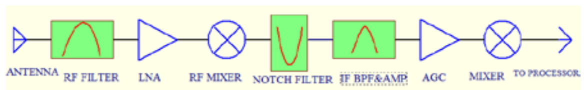

Fig. 1. Block diagram of a radar receiver

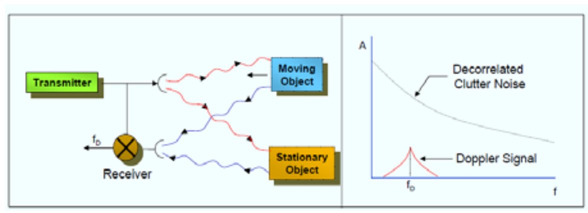

Fig. 2. The effect of noise on the Doppler radar systems

2. A crystal internal circuit

To design a crystal resonators filter model a simple circuit is equivalent to C_0 , L_m , r_m , C_m (Figure. 3.), r_m known resistance or piece of waste as well as ESR series of pieces. C_0 is composed of a fixed capacitor which are added to the metal body of the crystal, and a dielectric ($\xi r = 4.54$ for AT) between two metal electrodes in which the C_0/C_m is $200 < C_0/C_m < 500$. For instance, the AT-cut Fundamental (1–30M) C_m amount is $0.003pf < C_m < 0.03pf$. basically the crystal resonator L_m inductors are more constant (stable) at fundamental and overtone mode, but the C0 capacitance at overtone frequencies varies by a factor of $1/n^2$, (Where n is the overtone order). The crystal Q value of a resonant frequency is calculated by equation1. The overtone crystals have the third and fifth harmonics and mainly are used for the oscillators, while the fundamental cut crystals have no harmonics which are suitable for filtering purposes.

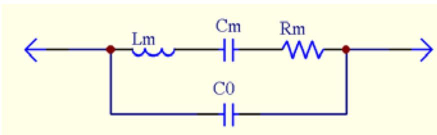

Fig. 3. The equivalent circuit of a crystal

$$Q_u=2\pi f_s L_m/r_m \quad (1)$$

$$f_s=1/2\pi\sqrt{L_m C_m}$$

$$Q = f / BW \quad L_m/(r_m+R_g+R_L) \quad (2)$$

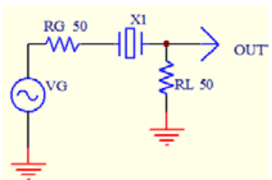

Fig. 4. Crystal circuit rm calculation

Table.1. Connect the circuit in Figure4. the amount of readed crystal drop With different r_ms by Spectrum Analyzers.

50 Ω	-3.5 dB
100 Ω	-6 dB
200 Ω	-8 dB
250 Ω	-9.5 dB
300 Ω	-11 dB
350 Ω	-12 dB
400 Ω	-13 dB
450 Ω	-14 dB
1050 Ω	-21 dB
1450 Ω	-23.5 dB
1950 Ω	-25.5 dB
50 Ω	-3.5 dB
100 Ω	-6 dB
200 Ω	-8 dB
250 Ω	-9.5 dB
300 Ω	-11 dB

According to equation 1 with increasing r_m, crystal Q decreases, there for in order to get better Q, the crystals with lower r_m are used. The calculated resonant circuit r_m on Figure.4.and the amounts of power loss to different rm s on Table.1.has been presented.

According to equation (2) with increasing frequency and the constant Q, The bandwidth increases and by decreasing frequency the bandwidth decreases Therefore, in order to get an increase in the width of the eliminating filter in radar IF frequency (8M-30M) and to avoid any impact on the other band width, some techniques are used to increase the width of filter band stop and Q filter, since a crystal resonator circuit on the simple mode can only eliminate maximum 10dB and the maximum filter band width is 1K. A crystal resonator circuit in Figure 5.a.The frequency response of the filter and filter bandwidth and the resonance frequency is removed in Figure.5. b. are shown

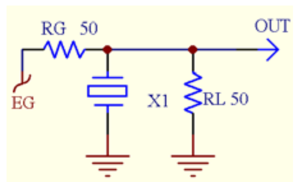

Fig. 5.a. Resonant circuit of a crystal

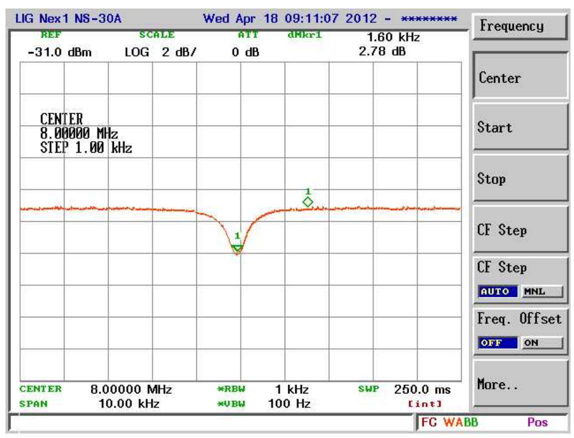

Fig. 5.b. Frequency response of single crystal resonator circuit in Spectrum Analyzer (BW_{3dB}=0.7K loss=3dB)

3. Resonant Circuit impedance increases by trans

With an increasing trans the circuit impedance can be increased, with increasing the resistance on the both of resonant circuit the filter band width and the amount of filter elimination increase. Meanwhile a reduction trans is placed in the output of the circuit to set back impedance to the original value and with a second trans the impedance and circuit conditions are returned (set back) to the initial state. Figure 6-a.showing resonant circuit and Figure6.b. showing frequency response of filter design by trance. Z= RG * 2^2 Impedance of the resonant circuit and V=EG*4 the voltage generated in the resonant circuit by increasing impedance. Input and output voltages at both ends of the crystal case current through the resonant frequency of the crystal is more so the increased impedance and voltage case the bandwidth of the filter and grade filter removes increase.

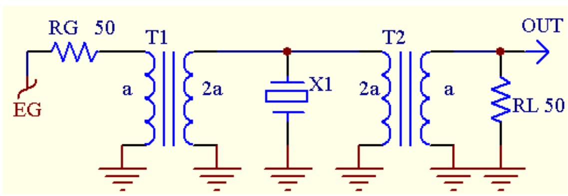

Fig. 6.a. Crystal resonant circuit with increasing trans

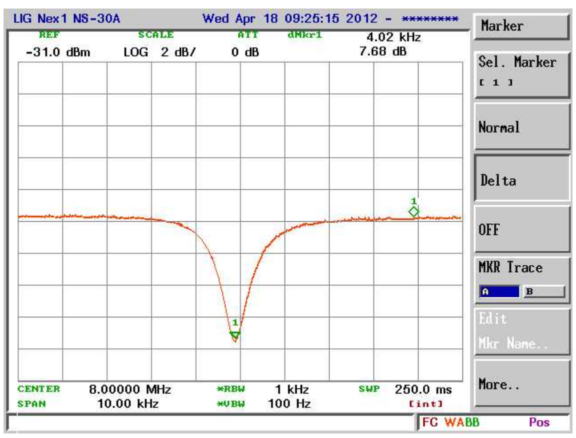

Fig.6.b. Frequency response of 6.a. circuit on the spectrum analyzer.

The lower IF (8M) frequency band width the grade filter remove decreased. Therefore in order to obtain a high-Q accurate and suitable bandwidth filter two BP filters in conjunction to each other and with by the distance of BW = $f_1 - f_2$ (Notch width) are used. In fact, the two BF filters create a Notch filter with the proper width and Q. Schematic circuit and frequency response are shown in Fig. 7.a. and Fig.7.b.

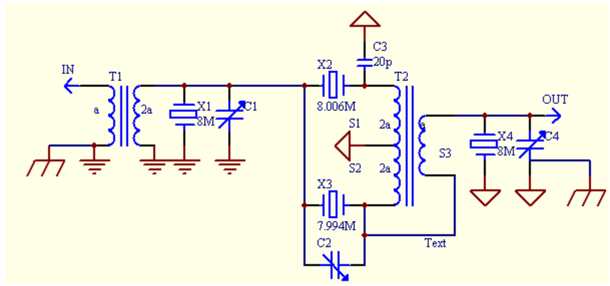

Fig. 7.a. The complete crystal filter circuit.

Fig. 7.b. A crystal filter response in the spectrum analyzer (BW_{3dB} =10K loss=60dB =10K)

4. Crystal filter circuit analysis

In this type of circuit in order to improve the input impedance is increased by trans T1. The Crystal x1 makes (creates) a Notch filter exactly on f_0 , then x2 and x3 crystals through the 6k distance from f_0 generate 2 BPF , The notch filter is created between two BPF with a width of about 10KHZ and the capacitor C_2adjusts the Notch filter band's output level. To avoid the C_0 adverse effect of x2 and x3 crystals, the BPF response of x2 and x3 crystals are induced on the T2 trans by using two S_3 and S_4 coils with are coiled 180 ° difference to neutralize the crystals C_0 capacitors, effect. The T_2 trans reduces the impedance and returns (sets back) the impedance to primary (initial) impedance. Finally, to get a greater depth in f0, the Crystal x4 generates a small Notch filter with the width of about 1k which leads to the generation of a 10K filter and a 60dB loss of f0. According to Equation 3, Doppler frequency return of the moving objects is proportional to the angular velocity of the moving object and the reverse transmitter wavelength. Doppler shift (F_D) for frequency (λ= wavelength) and different speeds (V) on Figure. 8. is presented.

$$F_{D=}2v\cos\theta/\lambda \qquad (٣)$$

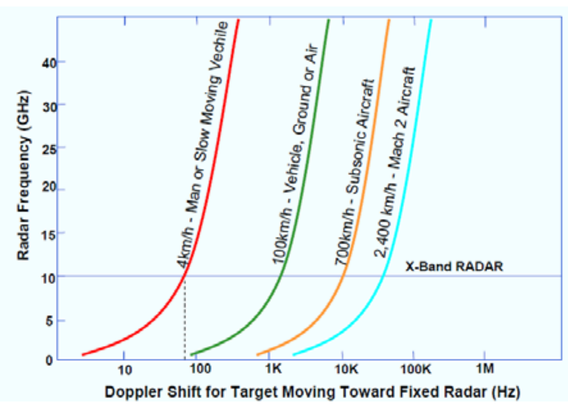

Fig. 8. Doppler shift for different frequencies

5. Notch filter circuit shielding

To avoid the effect of external noises on signals and avoid the heavy clutter effects circuit input to the other parts of the receiver, the Crystal filter circuit must be shielded and to be placed inside a metal box. To prevent cavity, the height of the box must be as short as possible and its size should be matched with the circuit size. Since the absorbents absorb the leakage of circuits, it is better to use absorbent inside the box to prevent leakage of the input noises and clutter to the output filter. Circuit Fiber must be connected to the box with small screws by 2 cm intervals until circuit ground and box ground are fully connected to each other.

6. Filter circuit PCB Design

The PCB Circuit must be designed in a way that bars creating track return and the long paths and whenever it is possible the signal path should be short and straight .The SMD parts (pieces) due to makes the signal path short and also due to equal size of connection points and inside parts which leads to prevention of popcorn noise. The Crystal case must be connected to the earth to prevent the impact of noise and circuit input leakage. The Circuit PCB must be designed in one layer and the fiber layer's bed must be on the ground so that the components which must be connected to the ground have shortest distance. Crystal filters have high Q and at the stop band (non passing band) have about 60dB weakening which means that The stop -band signal is attenuated by about a million times, there for to prevent leakage of input to the output possible the input and output connectors should have the maximum distance as much as possible.

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Conclusions

Crystal filters due to high Q, simplicity of its design, lack of leakage, no effect on other circuits, stability with the time, no need to supply voltage, stability against temperature and impact, are used in sensitive systems that need exact filter frequency and high Q. On the low altitude radar systems heavy ground return clutter and Doppler detection bandwidth are in vicinity, the crystal filters with high Q, exact center frequency and bandwidth of the filter are used to eliminate clutter and with no attenuation effect on Doppler reflective in a moving target. Although the crystal notch filters have a very little effect on the bandwidth but they weaken around 60dB on stop bandwidth. There for the crystal filters don't lead to a weaken Doppler on radars.

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