MODULATING SAW OSCILLATORS

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FM MODULATION

The possibility of frequency modulating SAW oscillators has been published by many manufacturers , but no one of the circuits proposed operate in a stable and repetable manner , in other words no one of those is useful in large quantity production. The circuits tested had problems of too narrow FM modulation (tipically 1 or 2 Khz , higly distorted) , the tendency to shift into LC oscillation mode or stopping oscillations at all. Since all those circuits operate with the principle of base modulation (change in base current, produces change in collector-emitter capacitances) one of the first tray we made, was to insert a varicap diode to increase modulation , but results were always poor. We discover instead that althought suggested manufacturer circuits are made with double ports devices, single port SAW's perform better and are capable of +/- 3 to +/- 5 Khz modulation, but again the tendency of the oscillator to shift in LC mode or to stop at all was always present.

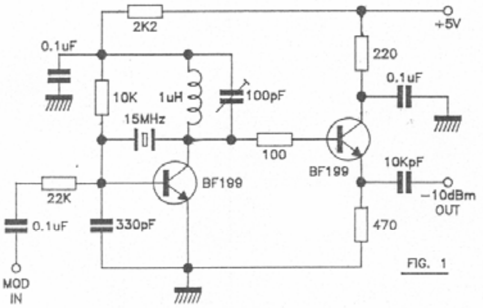

FIG. 1

At this point a different approach was taken: modify a FM modulated cristal oscillator (VXO) in a way to make it operating with a SAW. A"standard " building block was used (Fig. 1),a proven oscillator used in our projets for 15 years. This circuit is capable of FM modulating a 15 Mhz fundamental cut quarz cristal at +/- 4Khz, with a distortion of 10 % or less. The following substitutions were made: the LC collector circuit was replaced with a 60 nH air inductor and a 5 pF adjustable capacitor; the BF 199 transistor was changed with a higher frequency type, a BFW 92; the 330 pF base capacitor became a 2.2 pF and the 15 Mhz cristal was changed with a 300 Mhz single port SAW. Incredibly the circuit operated properly immediately, exibiting a +/- 10 Khz undistorted modulation with a 3 Vpp input and, best of all, the LC trimming was not critical, the oscillator did not exibit LC mode, even when it was mistuned.

A socket was mounted , to easy replace the SAW and a test of 50 identical SAW was accomplished: all oscillated whithout retuning and the modulation was fairly constant, in the 8-11 Khz range.

Since the original prototype was made for operation at 15 Mhz , it was build fairly large, in a way not too suitable for UHF operation. A second prototype was build in a more canonical way, with a proper ground plane, SMD components, and short connections.

Unfortunately Murpy 's law was still in force and the correctly mounted prototype operated in the worst way: it exibited a poor and distorted modulation, plus an extraordinary ability to oscillate in LC mode. Evidently in the "improper" layout a parasitic element greatly improved modulation and stability.

After a prolonghed try and repeat work, it was found that the fundamental parameter was a long emitter connection! In fact a 3/4 Inch wire in series with the emitter makes the difference between good or bad modulation. By inserting a small inductor (15 nH) in series to the emitter, the correct layout began operating very well, exibiting a +/- 15Khz modulation.

Some simulations done with SPICE did not explain the emitter inductor effect, but this can be imputed to the scarce reliability of SPICE models at UHF. My personal explanation is that emitter degeneration introduced by the inductor decrease the gain, stopping spurious oscillations (LC mode) and increase transistor input impedance, decreasing SAW loading, and in turn

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increasing the frequency pulling susceptibility of SAW, caused by the LC, and at last increasing modulation. By fact it was demonstrated that modulation was strongly dependent from output loading, and a clever decoupling between the oscillator and the buffer (.5 to 1pF coupling capacitor) turn the modulation to the +/- 20 Khz level, with a distortion tipically less than 10%, or alternatively an FSK modulation with 40 to 60 Khz in frequency shift. In this case remove the audio decoupling capacitor and apply proper DC bias. The final circuit diagram is illustrated in Fig. 2.

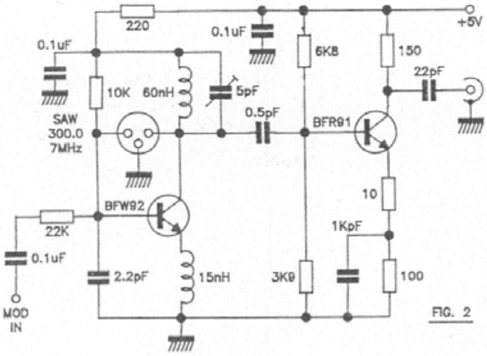

FIG. 2

The current draw from a 5 V supply is tipically 25 mA; the supply should be stabilised, otherwise change in tuning and in modulation will occur.

Single port SAW are recommended in FM applications, since they exibite lower loss, decreasing the possibility of spurious oscillations. The circuit of Fig 2 has stopped the experimentation, since it met specifications; but we belive there is room for furter improvements; a FET oscillator, for example can further decrease SAW loading, yelding wider modulation. It is to be considered that the oscillator of fig 1 if multiplied 20 times to reach 300 Mhz, will exibit a+/- 80 Khz modulation.

PULSE MODULATION

Pulse modulation in a SAW oscillator is normally obtained polarizing the base of the oscillating transistor with the modulating wave, or alternatively supply the whole oscillator with the modulating pulses.In this way the oscillator takes about 100 microS to turn on completely, limiting the maximum modulating frequency to few Khz. Some improvements can be optained matching SAW impedance with a series inductor, or with an LC network; increasing oscillator gain can also help.

Sometimes in certain circuis configurations you can observe very fast turn on time (10microS or less) ; in this situation oscillator start-up is in LC mode, and it sincronises lately with SAW. If you touch the oscillator with a fingher or a small metallic object in a hot point it will jump at another frequency, demostrating in this way LC oscillation mode.

If you need a faster modulating circuit, in Fig 3 you can see a diagram where the oscillator is keeped always alive , via the 220 Kohm base resistor and the modulation is applied contemporaneously to the base via a 22 Kohm resistor and to the driver directly as supply. Turn on and turn off times in the order of 5 microS and a carrier suppression of 45 to 55 dB are easy obtainable.

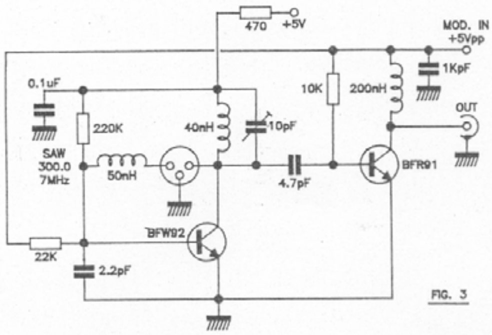

FIG. 3

A SUITABLE RECEIVER

Unfortunately SAW are used to have wide tolerances: +/- 250 Khz for low cost device, +/- 50 Khz at best.This is a figure 50 to 100 times worse than quarz cristal, moreover the tipical imprecision of +/- 2.5 Khz of a high frequency cristal can be tuned to exact frequency, while the wider error of SAW, at present, cannot.

The simplest way to overcome the problem is to made a receiver with a channel bandwidt wide enought to accept the SAW tolerance. Penalty for this arrangement is a worst signal to noise ratio, caused by the wider bandwidth .Choosing a SAW with a frequency tolerance of +/- 80 Khz, wich is a good price -performance compromise

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and considering to use a similar SAW on the local oscillator of the receiver, we obtain a minimum channel band width of +/- 180 Khz (80+80+20 Khz of modulation BW).
In receiver of Fig. 4 a 10.7 Mhz filter with a BW of 330 Khz was chosen. The receiver was built around an NE 605 SIGNETICS Ic, wich contains all the functions of a single conversion super-het receiver. Incidentally by proper component selection, the receiver can be build without tuning elements. The sensitivity is in the order of 1.5 microV: not so bad , considering that trasmitter is modulating+/- 20 Khz into a channel wide 330 Khz. The receiver can demodulate both FM or pulse modulation.(the last one is available at the output of RSSI, a logaritmic output signal proportional to the input level).
The input filter is a single cell type, with a bandwidt of 30 Mhz, if constructed with 1% components no tuning is needed.

The local oscillator is operating at 310.7 Mhz, and is constructed with an external transistor,since NE615 local oscillator is not able to oscillate at this frequency; signal is injected directly into pin 4.
The 10.7 Mhz filter is connected between mixer output and IF chain input. Since there are no tuned circuits to improve spurious signals rejection, it is recommended to use a good ceramic filter,at least a three poles, or better a four poles.
The discriminator can be built with a quadrature coil or using a ceramic detector. If the receiver is used for pulse modulation only the circuit can be omitted.
All the circuits above mentioned are described at a frequency of 300 Mhz, but they have been used from 200 to over 500 Mhz, with valuable results,so it will be easy to adapt them at different applications.

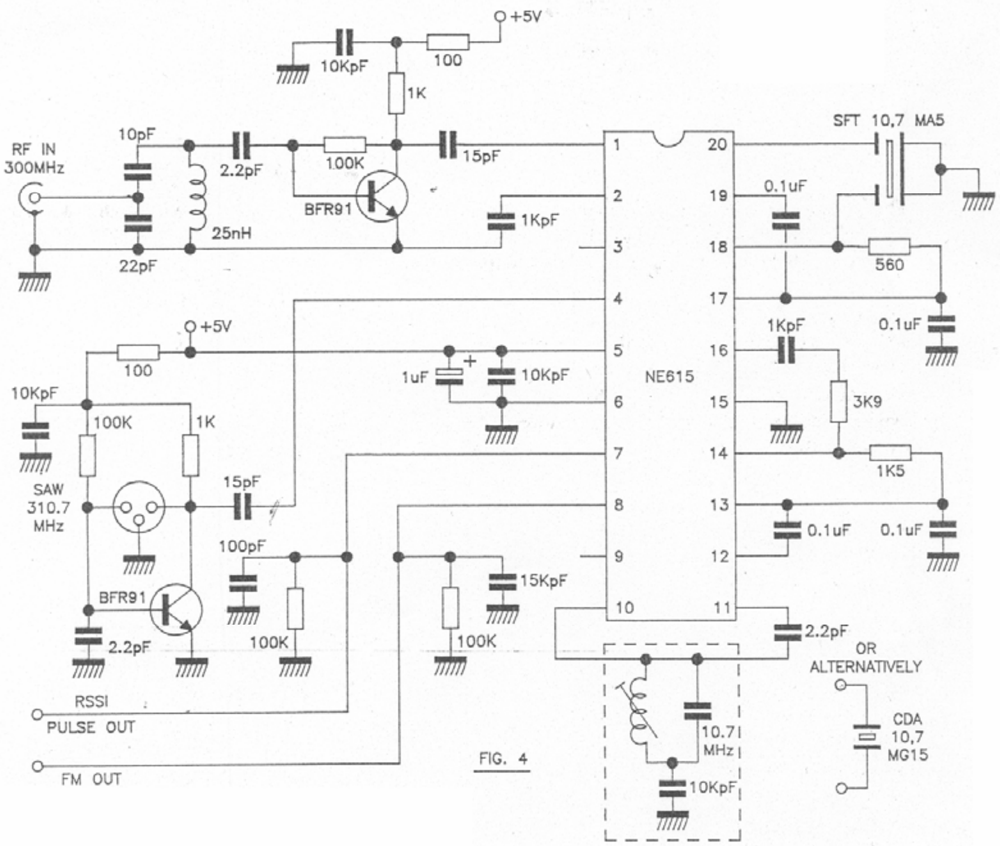

FIG. 4

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