INVESTIGATIONS OF TRANSPOSED GAIN OSCILLATORS USING LOW FREQUENCY LIMITERS AND AJC JITTER SUPPRESSION TECHNOLOGY

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ABSTRACT.

The Transposed Gain Oscillator was described by Page-Jones and Everard in the 10th EFTF [1]. The oscillator achieves low flicker phase noise at high frequency by breaking the oscillator feedback loop, mixing down to a low IF, at which a good noise figure and high gain can be achieved, and then mixing back up to final frequency. One purpose of this paper is to demonstrate the effect that an AM limiter can have on the final oscillator spectrum.

The Anti-Jitter Circuit (AJC) Jitter Suppression Technology for the reduction of phase noise and time jitter has been described in various EFTF papers [2-6]. A second purpose of this paper is to describe and characterise a proposed double transposed gain oscillator where an AJC jitter suppression circuit is used at 10 MHz to improve the phase noise of both the main oscillator and the secondary mixing down-and-up oscillator.

INTRODUCTION.

The Anti-Jitter Circuit (AJC) Jitter Suppression Technology for the reduction of phase noise and time jitter has been described in various EFTF papers [2-6]. The proprietary rights to this technology now belong to Toric Limited, a recently formed spin-out company from the University of Surrey.

In discrete component form, the highest frequency of the AJC implementation is at present from 10 to 20 MHz. It appears that chip bond wire inductance is a significant limiting factor. For a fully integrated AJC, simulations show that this will no longer be a significant limitation and then the highest frequency of AJC operation will be orders of magnitude higher.

The main purpose of this paper is to assess whether the technique used by Page-Jones and Everard in the "Transposed gain oscillator" [1] could usefully be used with a low frequency AJC to give a useful improvement of time jitter and phase noise at a higher frequency. In this case the intention is to apply the transposed gain technique not only to the feedback loop of an oscillator but also as an open loop " mix-down-mix-up" jitter reduction technique.

The transposed gain oscillator employs a secondary oscillator that in principle does not have to be low noise. The noise is cancelled provided sufficiently accurate delay equalisation is used. In the simulations presented in this paper we have modulated the secondary source with FM to confirm how accurate the delay equalisation has to be. We are also in also investigating ways in which a low frequency AJC may be able to "clean up" the secondary oscillator as well.

SUMMARY OF ANTI- JITTER CIRCUIT (AJC) OPERATION.

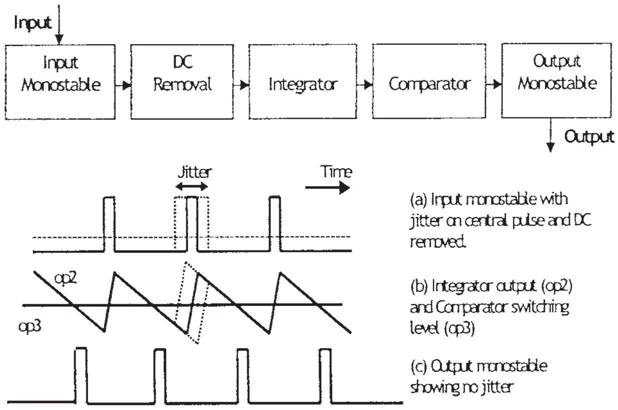

Fig1. AJC Block diagram and waveforms.

•The integrator converts the input pulse train into a sawtooth waveform with a constant or zero mean DC level, with no 'drift' up or down
•The comparator switching level is constant, usually chosen near the mean DC level.
•Time jitter on an input pulse does not affect the time of intersection of the slow (downslope) ramp of the integrator waveform with the comparator switching level.
•The output monostable, triggered from this intersection, has much reduced time jitter and phase noise.
•The (mark) pulse length of the output monostable can be chosen to be half a period (equal mark-space ratio).
•The lowest sideband frequency of jitter or phase noise suppression is the cut-off frequency of the DC removal part of the circuit.•The input monostable pulse DC is removed by AC coupling, or by DC feedback around the integrator.

Fig. 3 shows another candidate AJC circuit also having an adiabatic core A feature of this circuit is an extra rectification stage to boost the input voltage and hence the size of the integrator sawtooth voltage. This gives the AJC a lower noise floor.

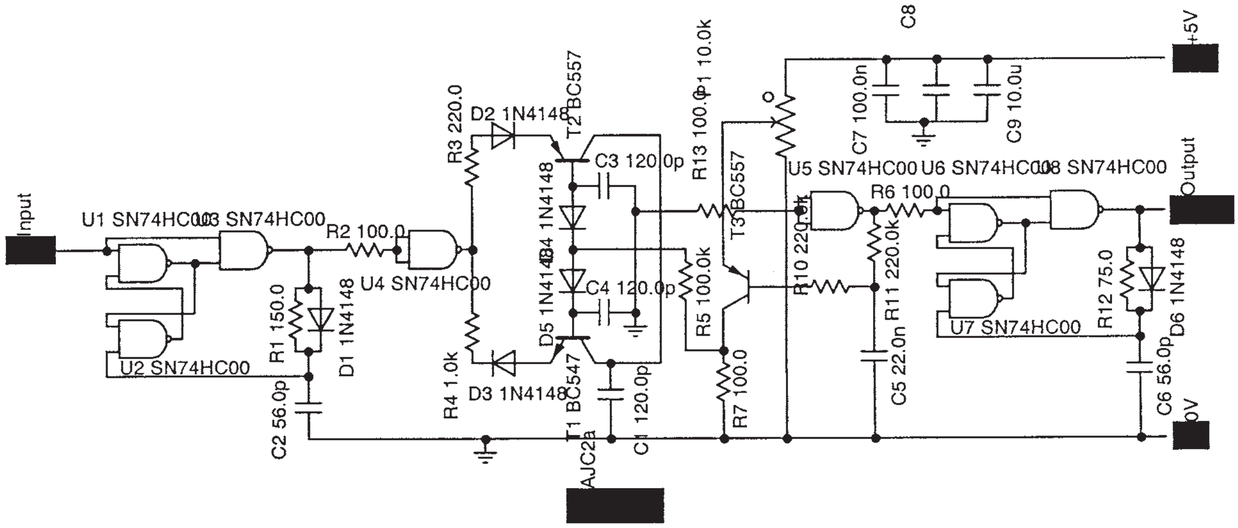

Fig. 2 Discrete component AJC circuit with adiabatic core.

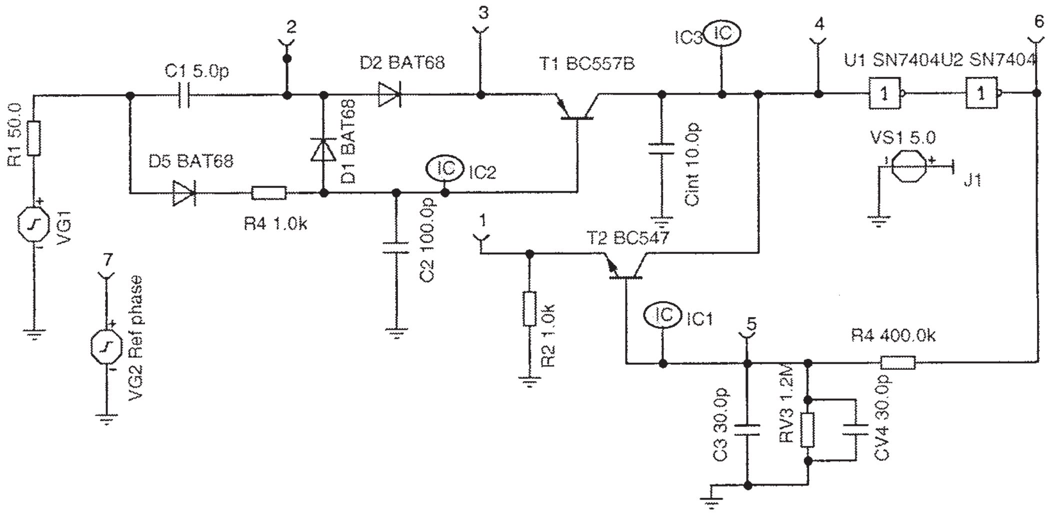

Fig. 3 Discrete component AJC circuit with voltage boost and adiabatic core.

TRANSPOSED GAIN MODELLING.

Fig. 4 shows a transposed gain oscillator block diagram. This has been used in a Spice simulation for the investigation of the transposed gain technique.

The principle of a transposed gain oscillator can be seen from this diagram. The first mixer X1 is supplied with an input oscillator signal from secondary oscillator source SRC1 via the power splitter PWR1. This mixer mixes down the input signal VRF1 to a (low) IF signal IF_1. The IF signal IF_1 is then amplified by RF – Amp X2 to become signal IF_2. Since it is at a lower frequency the amplifier RF – Amp X2 can have high gain and a very good noise performance.

The signal IF_2 is then fed to the second mixer X3, which mixes it back up, using a delayed version of the secondary oscillator signal, to become signal VRF_2 at the original frequency.

For the total circuit to oscillate some of the output signal must be fed back to the input with an overall loop gain of greater than unity. This is achieved by tapping off a proportion (v33) of the second mixer output signal VRF_2 using the directional coupler DR, X4. The main output is v22 shown taken to a 50 ohm load, R1.

When set up as an oscillator the "test" source SRC2 is replaced by a resonator or selective filter of some sort. Note that an AJC may now be placed in the low frequency part of the loop to reduce the overall system jitter. A good place is between the first mixer, X1 and the low frequency RF amplifier X2.

To simulate some of the properties of this circuit it is convenient to open the loop and use SRC2 as the original signal source. The circuit then operates as a mix-down-mix-up amplifier. It is then once again possible to place an AJC in the low frequency path to obtain jitter reduction, this time of an external signal source.

Figs 4 to 12 show the frequency spectra and voltage spectra obtained from the Spice simulation at various points in the block diagram circuit of fig. 4.

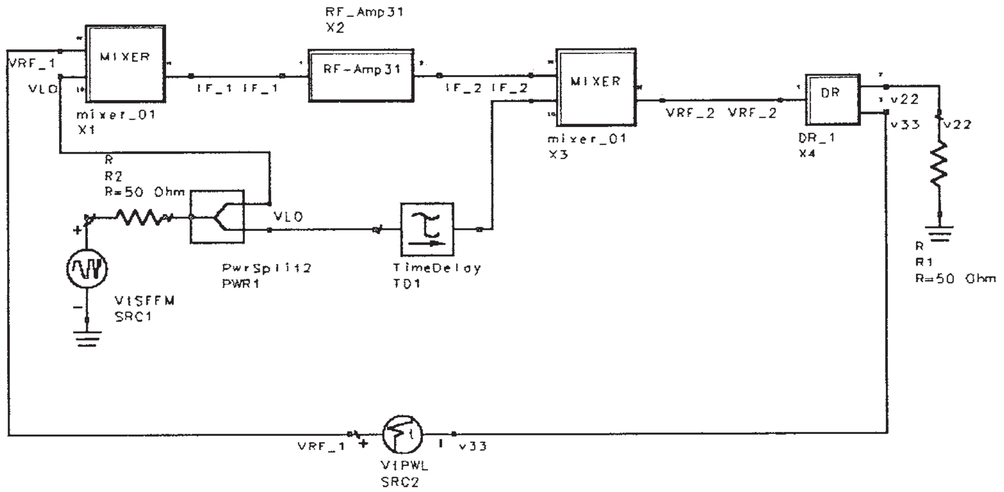

Fig. 4 Transposed gain oscillator simulation block diagram

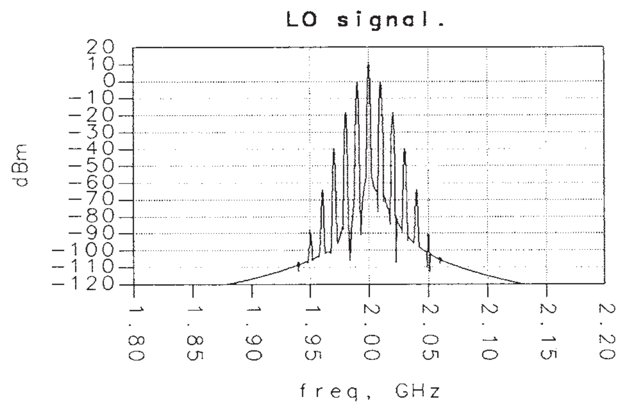

Fig 5a FM modulated secondary oscillator spectrum.

Fig. 5a shows the spectrum of the (LO) secondary oscillator spectrum at 2 GHz, with a modulation index of just less than unity and a modulation frequency of 10MHz.

The modulation frequency of 10 MHz is too high to simulate the operation of an AJC operating at 10MHz but using a lower frequency would have required the simulation time to be impractically long.

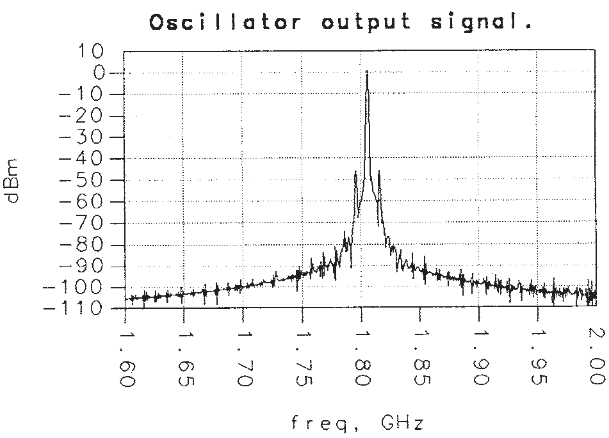

Fig 5b Test oscillator, SRC2, spectrum at 1.8 GHz.

The "test" oscillator, SRC2, spectrum at 1.8GHZ is shown in Fig.5b. It has a useful identifying sideband signature that is believed to be an artefact of the simulation.

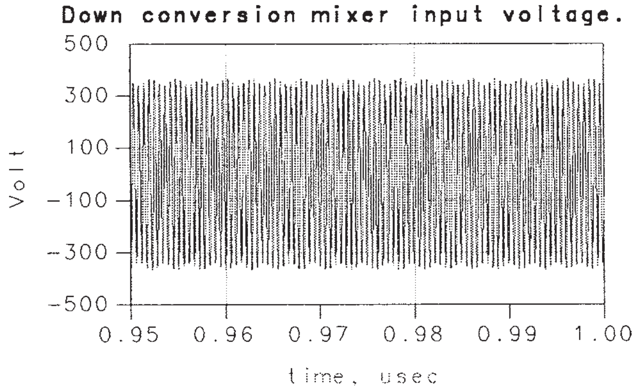

Fig. 6a First mixer input.

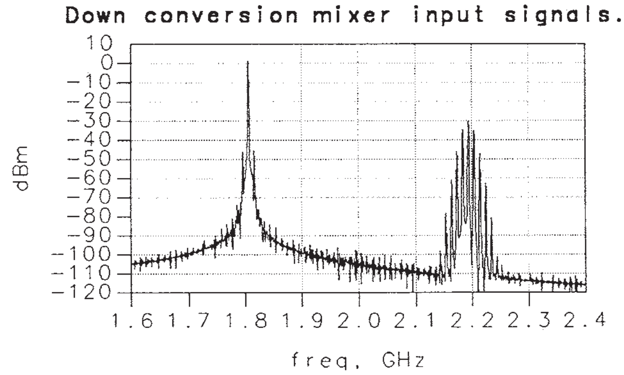

Fig 6b First mixer input spectrum.

Figs 6a and 6b shows a 2.2GHz input "opposite" sideband signal present at the input of the first mixer. In the open-loop case of no feedback this should not be present if the mixer has a good reverse isolation.

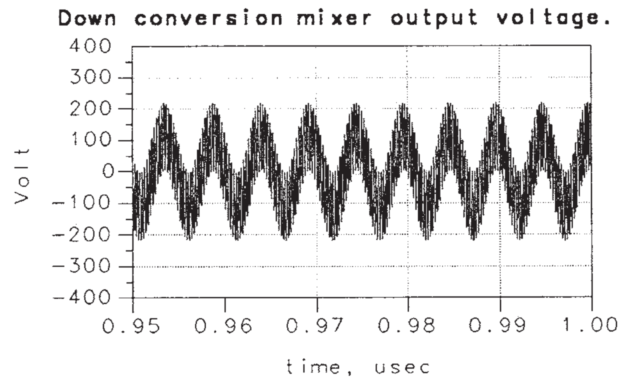

Fig. 7 First mixer output to IF amplifier

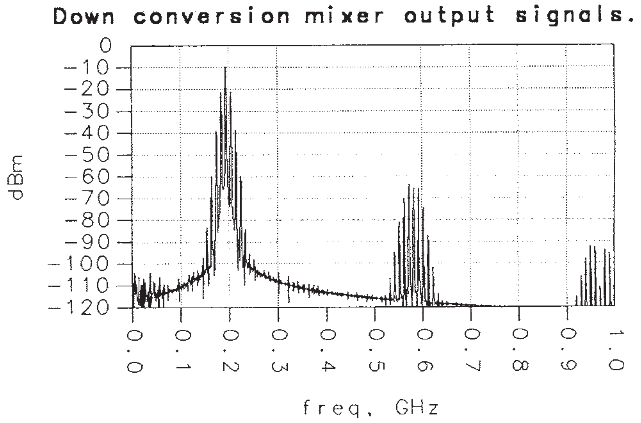

Fig 8 First mixer output spectrum

Fig.8 shows that the first mixer output signal of Fig.7 has an IF component at 200MHz which has FM noise from the secondary oscillator superimposed on it. This FM has to be exactly cancelled in the second mixer by a delayed version of the original secondary oscillator signal.

We have found from the simulation that the FM cancellation is better if this IF signal is put through an AM limiter, before being applied to the second mixer. Why this is so is not clear and is now the subject of practical and theoretical investigation.

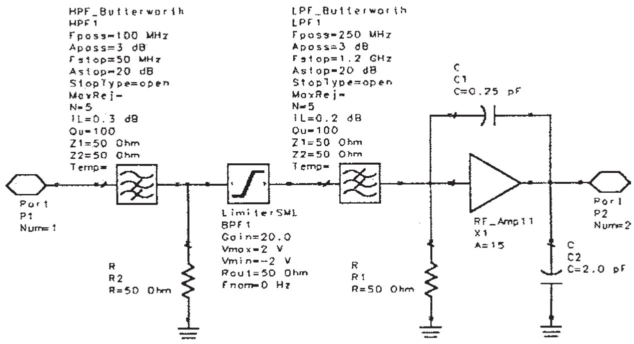

Fig 9 Limiting IF amplifier

Fig. 9 shows the limiting IF amplifier that has been used in the simulation. Fig. 10 shows the resulting spectrum rich in odd harmonics of the 200MHz IF signal.

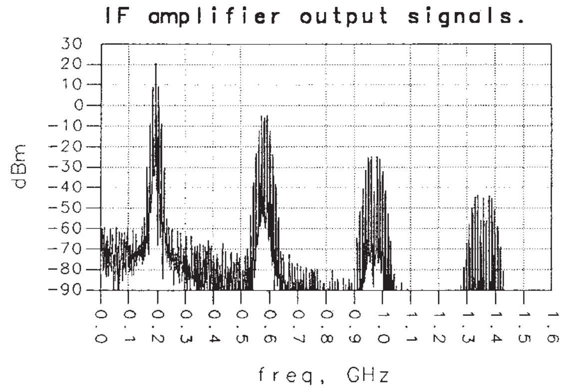

Fig. 10 IF amplifier output spectrum after limiting

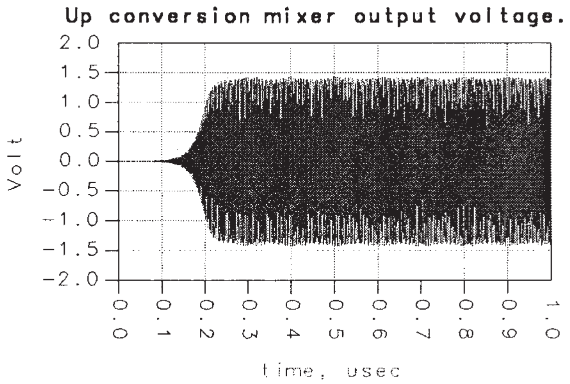

Fig. 11a Second (up-conversion) mixer output voltage.

Fig. 11a shows that the output from the second mixer takes some time to build up after the simulation is started. Clearly this may have some impact on the self-starting properties of the transposed gain. It will need to be investigated further.

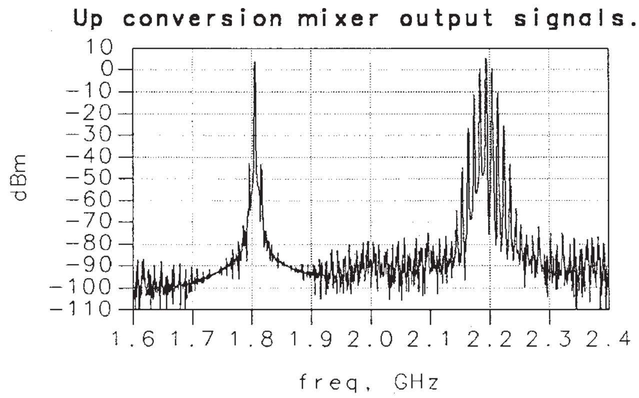

Fig. 11b Output spectrum of second (up-conversion) mixer.

Fig 11b shows that within the limits of the simulation the transposed gain technique produces a "clean" output at the original frequency, but with an upper side-band with all the secondary oscillator FM noise on it. An image suppression mixer is now being investigated to minimise this.

CONCLUSIONS AND FURTHER WORK.

Provided that a "clean" low-noise secondary oscillator is available, the AJC technique can be used at a low IF in a mix-down-mix-up transposed gain arrangement to reduce jitter on a high frequency source.

However if the secondary source is not clean the AJC will transfer the noise of the secondary source on to the output signal. For this reason we are investigating ways of using one or more AJCs to clean up the jitter on both sources at the same time.

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