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LabVIEW Based Phase Noise Performance associated with Microwave Analog Frequency Dividers Application for the Characterization involving Oscillators up for the Millimeter-Wave Range

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Abstract

The phase noise performance involving two different microwave analog frequency dividers we are characterized and compared by the values consumed applying effortless theories of noise with injection-locked systems. your current directly measurement of one'sdivider noise with a low phase noise synthesizer is not accurate enough, plus the residua! Noise system is used. your current noise levels observed utilizing the actual technique, between -120 AND -15!i dBc/Hz at the 10 kHz offset frequency, demonstrate that the divider noise can be crammed lower when compared with the phase noise regarding many microwave free operating oscillators, even if the noise is actually still high with respect for the residual noise of amplifiers realized with the same active devices. the down conversion associated with microwave sources up to be able to 40 GHz is usually proposed as a good application.

I INTRODUCTION

The frequency divider panel can be an extremely ought routine inside minimal cycle disturbance software for instance synthesizer phase to lock loops. Commonly static dividers, biased in digital camera circuits, are used to realize substantial department instructions and also large synchronization and widths inside quartz-stabilized HF sources. Even so, this performance of those circuits is limited by simply the phone number and also the sort of this transistors associated with their pattern, and also, above A wedding ring, generally, a good analog divider panel is needed. Your analog divider panel consists of just one or two effective products or simply nonlinear products. For that reason, it should be a smaller amount deafening for the identical device kind than the static divider panel. That also incorporates reduced electric power ingestion plus a maximum opl2rating volume. That is, theoretically, the ideal oscillation volume of the device associated with their pattern. This kind of volume will be strong inside millimeter say assortment regarding retail obtainable Ga As industry impact transistors nowadays. In a very PLL design, the top solution is probably for you to try to portion this indication together with a really routine right down to any volume is which often any silicon-based static divider panel can be used to device more this indication to the research supply. Your all-silicon static divider panel incorporates a pretty minimal component cycle disturbance (with regard for you to GaAs) [l] when aminimal cycle disturbance analog divider panel is needed as being an initial stage, this. all round step sounds on the process must keep on being minimal. Nevertheless, the actual analog divider step sounds performance inside the microwave variety is just not well-known. Almost all of the publicized the desired info is below 1 GHz [2]-[5], as well as most of these the desired info is incredibly offering along with step sounds amounts all-around -160 dBc/Hzat the 10 kHz balance out. Nevertheless, most of these final results are already obtained along with silicon circuits along with the requirement for experimental facts and/or concept pertaining to GaAs-based microwave analog dividers is increasing. A pair of new forms [6], [7] addressed the actual step sounds of mixer-based regenerative dividers inside the microwave variety. On this paper, a pair of different divider circuits tends to be researched regarding his or her step sounds: any harmonically synchronized FET oscillator as well as a good MMIC chilly FET-based divider. A variety of proportions carried out on most of these circuits tend to be presented, along with the desired info is balanced with your data computed coming from basic ideas of sounds in injection-lockedsystems. Really, all of us believe the different types of microwave analog dividers conduct themselves almost all as harmonically synchronized oscillators. The leading change in between most of thesea pair of systems is in which, for most dividers, there isn't a output indication inside the absence of a good suggestions indication even though any harmonically synchronized oscillator always provides a good output indication. Nevertheless, if the divider is below operation, possibly Miller's regenerative dividers [8] or perhaps self-biased FET dividers [9] conduct themselves like harmonically synchronized oscillators that have a frequency-to-phase marriage as well as a good Adler's-type [l0] locking bandwidth. In your judgment, simply the actual parametric divider which incorporates a incredibly broad locking bandwidth and is particularly handled below very high suggestions indication, may perhaps involve an even more difficult simple habits. This paper is structured as follows: the simple ideas of sounds in synchronized oscillators tend to be outlined; after that, the actual description approaches tend to be described, and then the actual description final results obtained about the circuits below analyze; ultimately, the outcome tend to be outlined, as well as a credit card application example is granted.

II OUTLINE

If the using assumptions are designed:

1) Analog partitioning act just like harmonically synchronized oscillators.

2) The harmonically synchronized oscillator is surely an injection-locked oscillator that has a reduce procedure performance.

Many of us can benefit from the traditional principle regarding disturbance throughout injection-locked oscillators [12]. Basically, many of us consider which the problem throughout while using pursuing equations seriously isn't throughout both of these hypotheses but alternatively inside the fact they've also been determined for a modest injection indication, in addition to, commonly, a powerful injection setting can be picked to trigger the divider panel. Kurokawa's principle prospects, for your result period disturbance of the injection-locked oscillator, for the pursuing partnership.

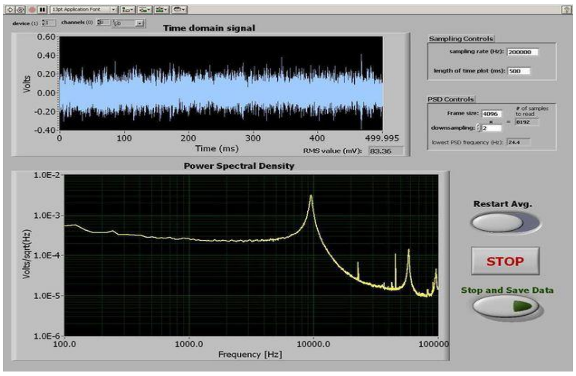

Fig1. Residual noise of a MESFET oscillator calculated from simplified Kurokawa's equation at

different input power/locking bandwidth *(B* = 2 * flock) in Labview.

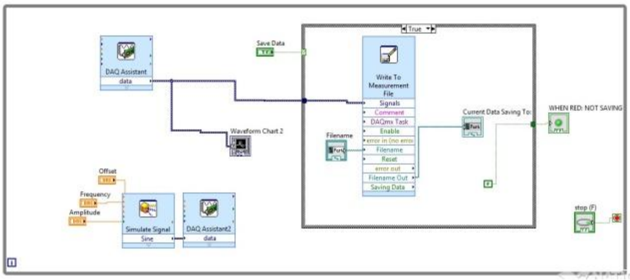

Fig 2 Block Diagram view in LabVIEW for the residual noise of a MESFET

$$S_\phi(\Omega) = \frac{1-\left(\frac{\Delta f}{f_{\text{lock}}}\right)^2}{1-\left(\frac{\Delta f}{f_{\text{lock}}}\right)^2+\left(\frac{\Omega}{f_{\text{lock}}}\right)^2} S_{\text{inj}} + \frac{\left(\frac{\Omega}{f_{\text{lock}}}\right)^2}{1-\left(\frac{\Delta f}{f_{\text{lock}}}\right)^2+\left(\frac{\Omega}{f_{\text{lock}}}\right)^2} S_{\text{free}} \quad (1)$$

$$S_\phi(\Omega) = \left(\frac{\Omega}{f_{\text{lock}}}\right)^2 S_{\text{free}}.$$

In this particular last situation, 5'4 would be the oscillator extra step noises in injection-locking setting. Fig. 1 demonstrates certainly one of the outcome received using this particular situation using a several GHz MESFET oscillator calculated on the free-running setting after which based simply by the procedure sign together with distinct procedure power/bandwidth. The particular ending extra step noises is at the stove from -150 for you to-160 dBc/Hz at a 10 kHz canceled out. One more procedure for evaluate the noises within a frequency divider is most likely the method with the lower frequency (LF).noise conversion. Frequently used in oscillators odeling. it has been used to evaluate the noise dependence on the input signal level or on the active device type in microwave analog dividers [14]. However, this approach suffers from the problem of LF noise dependence on the input power [15] and requires the intrinsic noise sources location in the active device. The results obtained with extrinsic noise sources for the 4 GHz MESFET oscillator are in the range obtained using the first approach We may conclude that the noise levels predicted by these simple models are quite optimistic for synchronized systems, and we have decided to check through the measurement if these values were effectively.

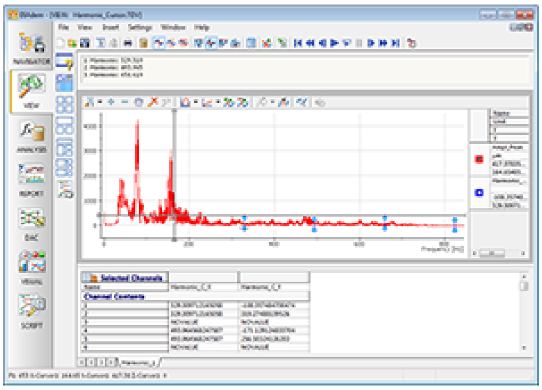

Fig 3 Harmonically Synchronized Oscillators

III MEASUREMENT AND CIRCUIT DESIGN

A couple strategies may be used to examine the synchronized oscillator or maybe a divider disturbance (Fig. 2). The primary the first is the supplier perturbation process, which usually has a comparison between your stage sounds of your small sound supplier in addition toyour stage sound of the similar supplier cascaded with the divider under check [Fig. 2(a)]. In our experimental set-up, a Anritsu/Wiltron 69147A synthesizer (California) had been used for the reason that reference point supplier, plus the stage sound had been scored with a postpone line discriminator. This technique is fixed by means of your suggestions supplier sound, in addition to, often, just this kind of sound is actually witnessed in the productivity, separated through the divider section percentage. It can be and then needed to utilize residual stage sound approach [16], when the suggestions supplier sound is actually canceled. The only real tough point is actually that, for any divider, 2 the exact same circuits are needed to deliver your, similar volume upon the two ports of the stage detector [Fig. 2(b)]. The rating tenderness is actually and then just restricted to your sound of your stage detector dry of the using LF amplifier. The suggestions stage sound is actually canceled by means of small delays within the 2biceps in addition to, generally, your suggestions supplier WAS sound is actually far more bothersome when compared with their FM sound. A couple of distinct circuits have been characterized. A MESFET-based harmonically synchronized oscillator (Fig. 3) in addition to the MMIC Ku-band divider by means of 2 (Fig. 4) with regard to that your electro-mechanical characteristics tend to be described somewhere else[17]. The 1st circuit relies on a FET (Vd = 3 V) picked with regard to their good LF sound attributes. The second circuit is situated over a cool FET (more precisely, a PHEMT having Vd = 0V and Vg # 0 V) and is an intermediate design between aparametric and a regenerative divider.

IV MEASUREMENT RESULTS

Our first attempts to characterize the dividers phase noise with the perturbation of a low noise source [method of Fig. 2(a)] have been unsuccessful. The source phase noise divided by the division ratio has been observed at the higher frequency offsets (about -120 dBc/Hz at a 100 kHzoff set from a 4 GHz output), and the delay line discriminator noise floor has been observed closer to the carrier. This experiment is only the confirmation that dividers phase noise is much lower than (free running) oscillators phase noise and that only a residual noise technique can provide valuable information on these systems. Therefore] a residual noise system has been used for further investigations. The data shown in Fig. 5 correspond to a 4 GHz MESFET oscillator synchronized on the fundamental harmonic. These results have been obtained near the center of the locking bandwidth. Contrary to the theory, they do not correspond to the minimum noise, which isa few decibels lower (about 5 dB) and which is not systematically observed at the center of the locking band. Never the less, we have reported the spectra shown in Fig. 5 because they represent more closely the typical performance of such a circuit. If we compare these spectra with those of Fig. 1 (calculated for the same circuit), it is clear thatthe noise levels observed are higher (about 10 dB) than the calculated ones. This discrepancy is probably due tothe high injection mode. Finally, it is noteworthy that the noise from 10 Hz to 40 kHz in Fig. 5 is effectively due to the MESFET device, and the upper frequency region of the spectrum is perturbed by a parasitic AM detection of the synthesizer. Indeed, the positive slope observed on the spectra near 100 kHz is nonphysical for a single transistor circuit and does not correspond to the spectrum shape observed on this device while measuring its LF noise (drain

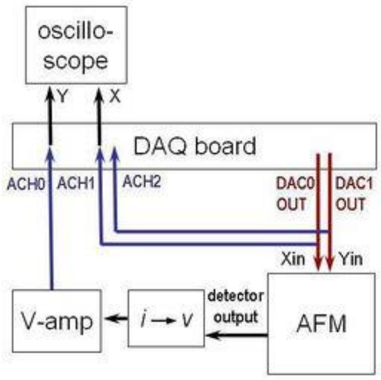

Fig 4 Block diagram of the MMIC

Current vacillations at baseband). In the separating mode (Fig. 6) this parasitic impact is not watched in view of the divider's regular AM separating conduct. The results delineated in Fig. 6 compare to the same circuit synchronized on music 2, 3, and 4 (information frequencies8, 12, and 16 Ghz, separately) with a consistent information force of around 0 dbm on the divider dynamic gadget. The stage clamor stays low regarding free-running oscillators, even on symphonious 4. This commotion information can be associated to the locking data transmission of one of the two circuits. Really, the two dividers utilized within the examination were not precisely indistinguishable. One was settled on a resonator; also the other one was balanced out on a postponement line. The Q variables were marginally distinctive; however the dynamic gadget in each one circuit was the same and was utilized within the same way (predisposition and burden conditions). An increment of the Q component actuates an abatement of and run in the same extents what's more, after (2), ought to have no impact on the stage commotion. In any case, it is hard to superpose splendidly the locking data transfer capacities of the two circuits and to measure these two dividers under precisely the same conditions. In this way, we have made the supposition that the watched clamor is the commotion of one of the two circuits, and we didn't subtract the established 3-db component. Correlations of these clamor information with the qualities Table 1.

TABLE I

COMPARISON BETWEEN INJECTION LOCKING THEORY AND EXPERIMENT FOR THE 4 GHz MESFET-BASED HARMONICALLY SYNCHRONIZED OSCILLATOR.

Harmonic no.	Locking bandwidth $B = 2f_{\mathrm{lock}}$ (MHz)	Measured phase noise S_ϕ at a 10 kHz offset (dBc/Hz)	Calculated phase noise $\left(\frac{\Omega}{f_{\mathrm{lock}}}\right)^2 S_{\mathrm{free}}$ at 10 kHz (dBc/Hz)
1	18	−147 (best value)	−154
2	5	−138	−143
3	8.7	−146	−148
4	0.9	−131	−128
5	0.7		−126

There is a genuinely decent concurrence with this hypothesis in the event that we consider the estimation vulnerabilities; also it is clear that the stage clamor takes after the varieties of the locking data transfer capacity. Likewise intriguing to note is that the infusion effectiveness does not deliberately diminish as the consonant request increments. A critical exemption is consonant 3 for which a huge locking transmission capacity and a low stage commotion is gotten. This is predictable with the unique state of the Id(vg) nonlinear trademark for the MESFET gadget, which frequently creates an abnormal state of consonant 3 and which is some of the time displayed utilizing a third-request polynomial representation [18]. Calculated utilizing the infusion securing hypothesis is introduced Fig. 7 demonstrates the best stage commotion saw with the MMIC divider by two over its bolting data transmission. In this range (11.8 to 15.7 Ghz at the information), the stage commotion stays between -141 and -124 dbc/Hz at a 10 khz counterbalance. These qualities are, by and large, higher than the ones measured utilizing the MESFET divider, however this is presumably because of the decision of the dynamic gadget: a HEMT transistor produces a higher clamor level at baseband frequencies than does a MESFET transistor. For this situation, the two circuits were precisely indistinguishable, and it was not difficult to examine the clamor versus the recurrence balance from the core of the locking transmission capacity. Shockingly, the commotion was not at any rate at the core yet rather on the edges of the locking data transfer capacity. This conduct is the inverse of what is portrayed by the infusion locking hypothesis. Be that as it may, the examination with this hypothesis is exceptionally troublesome for such a circuit on the grounds that there is no yield signal without a data signal (what is Sf) and since a high infusion level is required to prompt a isolating conduct on this detached circuit (frosty FET).

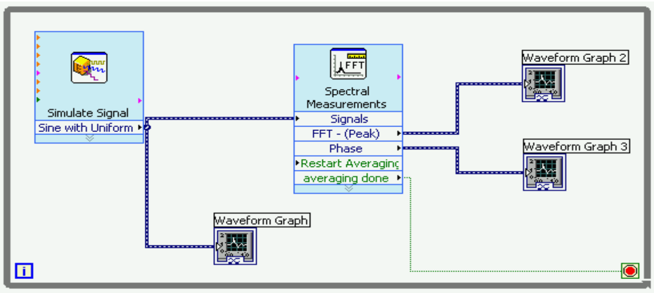

Fig 5 Block Diagram view of Harmonically Synchronized Oscillator

As a sample of how to profit from these low clamor properties, we have utilized a simple recurrence divider to develop the estimation scope of a deferral line recurrence discriminator. This discriminator was at first constrained to the 2 to 18 Ghz range, basically by the stage finder properties. Additionally, in the 12 to 18 Ghz reach, its affectability is debased as a result of the misfortunes in the postponement line and of the restricted affectability/commotion execution of the stage identifiers. It is then proposed to use as a to start with stage the long ago portrayed agreeably synchronized oscillator with a specific end goal to gap the sign into the 2.5 to 4.5 Ghz extent, to measure the partitioned sign stage commotion, also to find the data stage clamor by the expansion of the division variable of 20 log(n). The estimation technique takes after. A sub harmonic recurrence is picked in the scope of 2.5 to 4.5 Ghz. The resonator included in the divider circle is tuned to this recurrence, and the oscillator is turned on. The synchronization happens and is controlled on a range analyzer. At last, the stage clamor is measured. An alternate peculiarity of this technique is the characteristic AM dismissal, in light of the isolating first stage. This dismissal has been measured to be in the scope of 20 db for a divider by two. Really, the level at the discriminator data is the immersion level of the divider dynamic gadget. It is an imperative change, giving that the AM commotion of the divider itself is not identified and does not result in a commotion floor debasement. The commotion floor of the entire framework at 4 Ghz is in the scope of -120 to -125 dbc/Hz at 10 khz and is debased by 201og(n) at the upper frequencies (e.g., -100 to -105 dbc/Hz at a 10 khz balance at 40 Ghz). The aftereffect of this sort of estimation is demonstrated in Fig. 8 for two sources, a 24 Ghz dielectric resonator oscillator

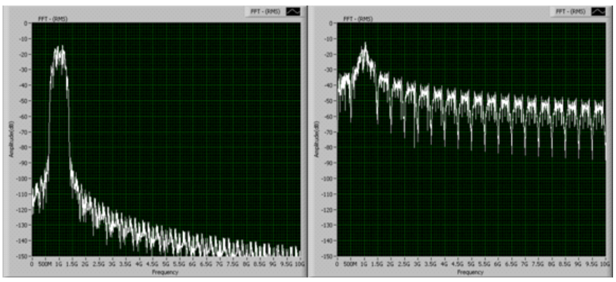

Fig 6 Frequency in Ghz using LabVIEW in the resonator oscillator

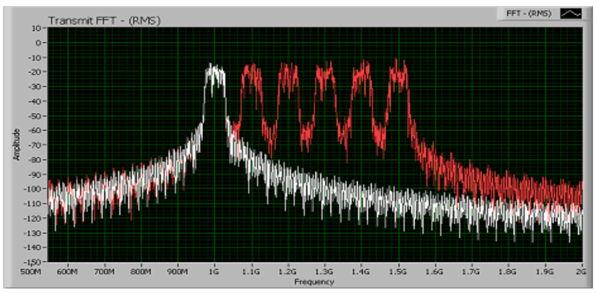

Fig 7 Phase noise measurement of a 24 GHz DRO and of a 36 GHz synthesizer using the synchronization of a 4 *GHa* oscillator on its sixth and ninth harmonics.

(DRO) and a 36 Ghz synthesizer. The estimation has been made through the synchronization on sounds 6 also 9 of a 4 Ghz oscillator. A traditional down change technique has likewise been utilized for the 1) ro estimation: blending with a low commotion 10 Ghz source and measuring the 14 Ghz signal. The two routines (blending and division) have given the same results. The main discriminating necessity for such an estimation is the source under test yield power, It ought to be sufficient to instigate a locking data transmission much bigger than the estimation range. In this case, 10 dbm of force were accessible at the yield of these sources, and the first debasement of the estimation commotion floor with, much a yield level has been taken noteon a tenth request synclironization (40 Ghz). Going further in the consonant request ought to be conceivable, nonetheless, and an simpler route than the increment of the yield force is presumably the increment of the nonlinear conduct by the expansion, in the divider circle, of an unequivocally nonlinear component (e.g.: a Schottky diode).

V CONCLUSION

The stage commotion of two diverse microwave simple dividers has been portrayed. For the first circuit, the correlation with a basic model of noise in synchronized oscillators demonstrates a decent qualitative concurrence with this hypothesis and exhibits that it can be utilized as a first rough guess to ascertain a divider stage commotion. The clamor levels saw on both circuits stay low with deference to the clamor of free-running oscillators, gave that the synchronizing force stays sufficiently high (around 0 dbm at the dynamic gadget info port for the majority of the circuits tried). One of these circuits has then been utilized to augment the estimation scope of a postponement line recurrence discriminator from

2 to 18 Ghz to 2 to 40 Ghz. This straightforward framework has the capacity describe any voltage controlled oscillator (VCO) and most DRO in this recurrence range.

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