FAST STARTING, PULSE PRIMED DROs WITHOUT PHASE NOISE DEGRADATION

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ABSTRACT

Starting time improvements of as much as 700 ns (over 60%) and virtual elimination of the associated jitter is presented for series feedback DROs by uniquely applying a pulsed priming signal. Since resonator Q reduction is not required, the inherent oscillator phase noise is not degraded. The present technique of introducing the priming signal still allows for electrical tuning of the oscillator. Finally, an X-band pulse primed DRO is presented which starts in 60 ns without any observable starting time jitter.

INTRODUCTION

Over the last few years there has been a considerable amount of information presented on the Dielectric Resonator Oscillator as an attractive microwave source. However, most of the published work has highlighted the CW characteristics of the DRO. The reported efforts relating to the pulsed performance of this important component have either discussed starting time improvement with attendant phase noise degradation [1] or presented novel techniques for reducing the settling time in multi-oscillator assemblies [2]-[4]. Fast starting times are important in pulsed systems because the narrower pulsewidths provide greater radar system resolution. This paper briefly reviews the factors affecting starting time for the series feedback DRO configuration and reports on the implementation of a pulse priming technique which significantly reduces the oscillator starting time and jitter without degrading the phase noise.

The example oscillators for which data is presented are based on a variety of GaAsFET devices. The two discrete devices used include the NEC NE710 series and the Harris HMF0620. Figure 1 shows the NEC device incorporated into a solid-state X-band pulsed power amplifier. This DRO has electrical tuning capability and the entire assembly delivers 25 Watts of peak power.

CONVENTIONAL DRO STARTING TIME

The two parameters of the series feedback DRO that directly affect the starting time performance are the resonator loaded quality factor and the transistor "reflection gain," Γ_t, as defined in Figure 2. The overall time constant τ_{tot} for the build-up of oscillations in the DRO can be considered to be dependent upon the resonator time constant τ_r

$$\tau_{tot} \propto \tau_r = \frac{2Q_l}{\omega_o} \tag{1}$$

and upon the open-loop gain of the system [5] as given in equation 2.

$$\tau_{tot} \propto \frac{1}{20\log|\Gamma_r\Gamma_t|} \tag{2}$$

Usually, the open-loop gain is dominated by the reflection gain. Reducing resonator Q will improve starting time but will also degrade oscillator phase noise performance. The other obvious method of obtaining faster start-up is to increase the reflection gain, Γ_t. This parameter is usually increased by proper matching of the drain port of the FET. However, this technique also results in worse phase noise performance [5] and is substantiated by the measured data presented in Table 1. This data is based on a DRO built around the Harris HMF0620 device. This review has shown that attempts to reduce starting time by either lowering resonator loaded Q or increasing the reflection gain generally result in degraded oscillator phase noise levels.

PULSE PRIMED DROS

A method that significantly reduces starting time of the DRO without sacrificing phase noise is the pulse priming technique shown in block diagram form in Figure 3. This technique has been used in the past for various sources, from diode based units [6] to gyrotrons [7]. The priming source could be a signal obtained from

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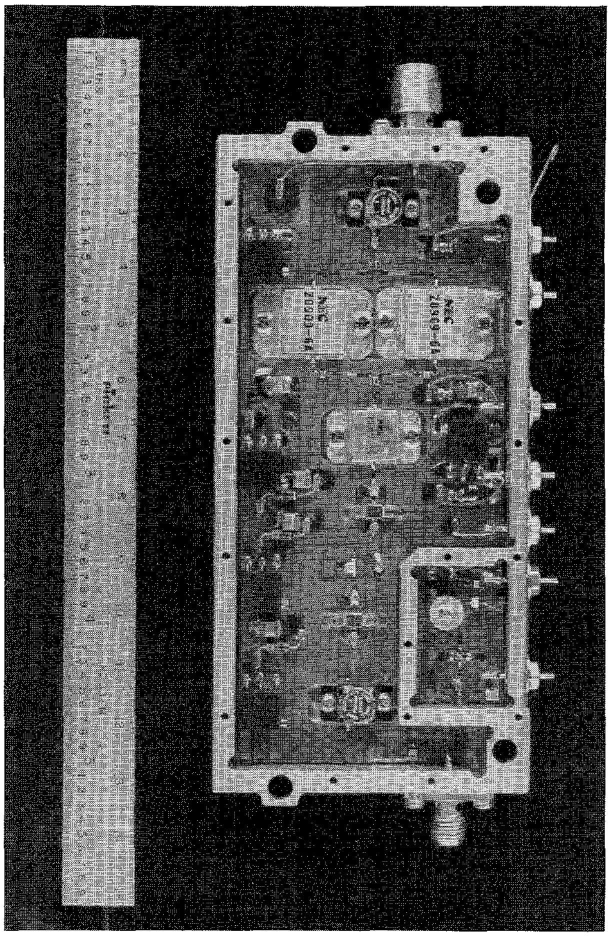

Figure 1

DRO Integrated with Pulsed Amplifier

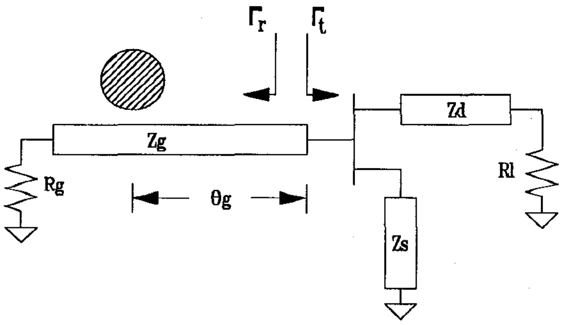

Figure 2

Series Feedback DRO Configuration

a typical radar system's local oscillator, from a multiplied reference, or a source solely dedicated to the priming function. The priming signal is somehow applied to the main oscillator shortly before pulsing it on.

The concern of applying this technique to a series feedback DRO is how to couple this energy into a circuit topology that still maintains electrical tuning capabilities. Since the start-up process is initiated by noise in the resonator/transistor system, introduction of the priming signal in this area would seem to be the logical choice. However, the electrical tuning circuit usually occupies one of the available "sides" of the resonator. The other side is needed to couple between the resonator and the transistor. A third coupling line could be introduced, but would further degrade the resonator quality factor. One possible solution is shown in Figure 4. A resistive pad on the gate line still provides the functions of the replaced 50 ohm termination by acting as a dc reference to ground for self-biased configurations and also as a termination for any possible out-of-band oscillations. It also allows introduction of the priming signal without sacrificing electrical tuning potential. A properly chosen isolator could also be used at a higher cost, but has the advantage of less attenuation, thereby requiring a lower net priming power.

MEASURED RESULTS

Figure 5 is an oscilloscope plot illustrating a notable improvement in starting time and virtual elimination of jitter by pulse priming the Harris HMF0620 based DRO. The leading edge of the response in the non-primed condition is not well defined due to the pulse-to-pulse starting time jitter. Figure 6 shows that very little power is required to significantly reduce jitter. Figures 7 and 8 depict starting time improvement in graph form as a function of power level and frequency of the priming signal for the Harris and NEC based designs, respectively. The extent of the improvement is controlled by the frequency and magnitude of the injected signal. This is consistent with the concept of resonator quality factor in that the resonator accepts or stores energy according to its effective bandwidth as defined by Q_l. A settling time plot is shown in Figure 9 and Table 2 contains a summary of the results for the two units.

CONCLUSION

A pulsed priming technique has been applied to series feedback DROs. Using this method, a DRO was presented which electrically tuned over .4%, started in 60 ns without observable starting time jitter, settled to within +/- 10 ppm in 150 ns and delivered an output power of 14 dBm with a phase noise level of -92 dBc/Hz. A fixed tuned DRO also showed over a 700 ns

Γ_t Gain (dB)	Q_l	Starting Time	Phase Noise @ 10kHz offset
9.5	222	100 ns	-82dBc/Hz
9.5	487	225 ns	-85dBc/Hz
3.8	222	350 ns	-90dBc/Hz
3.8	487	1000 ns	-95dBc/Hz

Table 1

HMF0620 Based DRO Performance @ 9.5 GHz
(Starting Time = 50% Bias Pulse to 90% Detected RF)

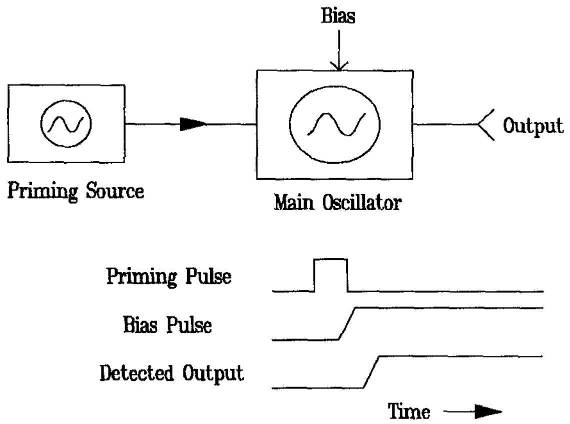

Figure 3

Block Diagram of a Pulse Primed System

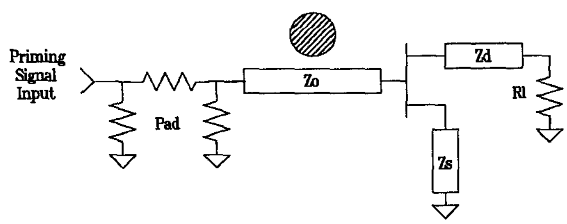

Figure 4

Application of Pulse Priming
to a Series Feedback DRO

improvement in starting time when pulse primed with a phase noise level of -95 dBc/Hz. One important topic that deserves further investigation is the degree of pulse-to-pulse phase coherency obtainable in pulse primed DROs.

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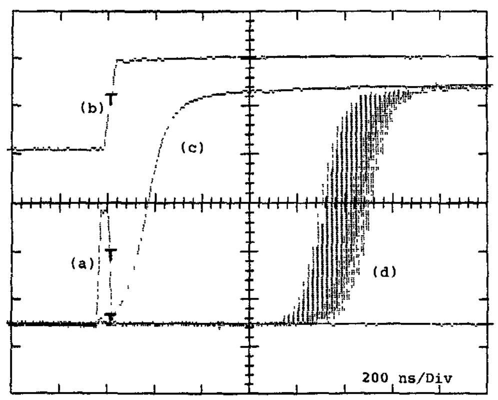

Figure 5

Oscilloscope Plot of HMF0620 Based
Pulse Primed DRO
(a): Priming Pulse (b): Drain Bias (c): Detected Starting Time (d): No priming with Jitter

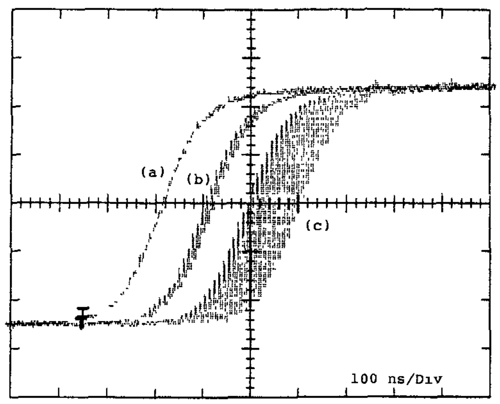

Figure 6

Starting Time Jitter vs. Priming Power Level
(power referenced to resonator, @ 9.5 GHz)
(a): - 50 dBm (b): - 60 dBm (c): -70 dBm

Unit	Γ_t (dB)	Q_l	T_{strt} (ns)	T_{set} (ns)	L(f) (dBc/Hz) @ 10kHz
HMF0620					
Stand Alone	3.8	487	1000	---	-95
Pulse Primed	3.8	487	260	440	-95
NE71084 E-tuned					
Stand Alone	8.3	292	180	325	-92
Pulse Primed	8.3	292	60	150	-92

Table 2

Summary of Stand Alone vs. Pulse Primed Results

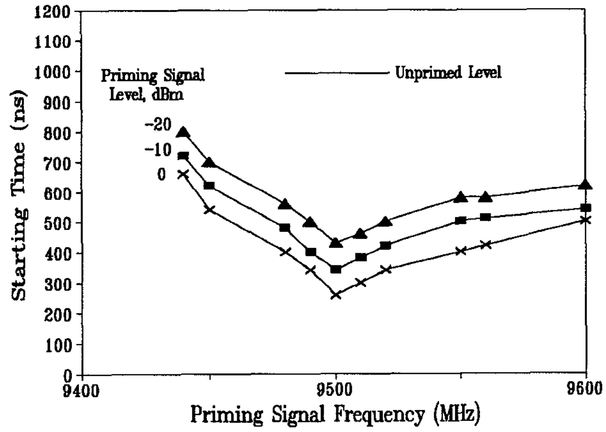

Figure 7

Harris HMF0620 Pulse Primed Results

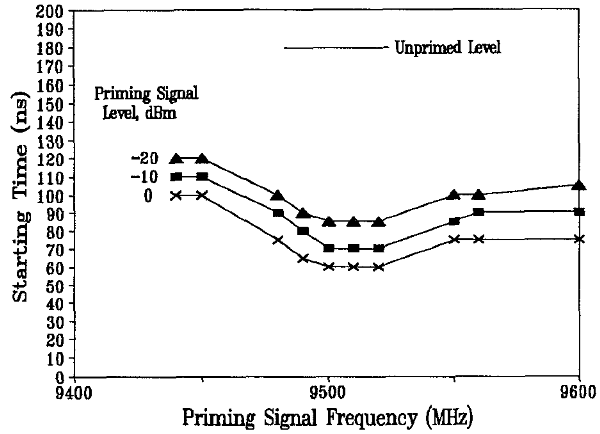

Figure 8

NE71084 E-tuned DRO Pulse Primed Results

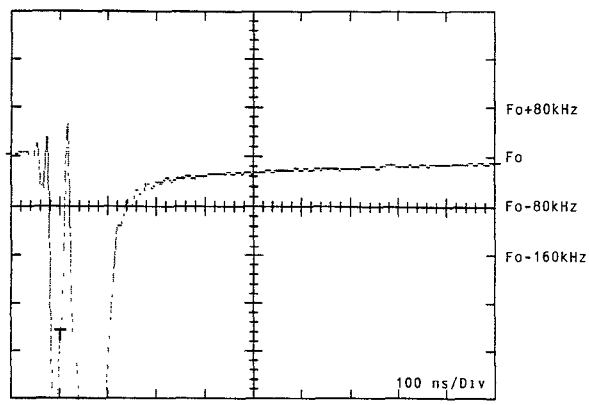

Figure 9

NE71084 DRO Settling Time Plot