HIGH SPECTRAL PURITY MICROWAVE OSCILLATOR USING AIR-DIELECTRIC CAVITY

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to provisional application Ser. No. 60/486,524 filed Jul. 11, 2003, the contents of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a low noise microwave oscillator. More particularly, the present invention relates to an oscillator using a high power radio frequency (RF) input into an air or evacuated conventional resonator to reduce noise.

2. Description of the Related Art

Microwave oscillators of high spectral purity are required as a local reference or clock signal in secure communications protocols, very high-speed jitter-sensitive modulation-demodulation schemes, and high-resolution digital signal processing applications such as imaging radar. These oscillators are designed to produce an oscillating signal at one frequency, the resonant or carrier frequency ν_{res}, and to use a technique in which phase noise that is offset from ν_{res} by Fourier-frequency f is detected by the oscillator's resonator and subsequently suppressed. The methods of detection and strategy for suppression vary, but these two functions are common to the best oscillators.

The chronological stages of development of prior art by earlier inventors can be summarized as follows.

U.S. Pat. No. 4,555,678, issued Nov. 26, 1985 to Galani et al., the contents of which are incorporated herein by reference in their entirety, discloses using a high-Q cavity-based discriminator to degenerate (or cancel) noise in a microwave oscillator of the Direct Feedback Loop type. Subsequent inventors have not changed the basic concept of the cavity discriminator but have only added incremental changes to improve its performance and the extent of noise cancellation achieved. For example, U.S. Pat. No. 5,032, 800, issued July 1991 to Galani et al., the contents of which are incorporated herein by reference in their entirety, 1991 teaches improved predictability of the feedback technique by introducing a voltage controlled phase shifter to vary and compensate the oscillator loop, and a noise-induced phase shift in accordance with the discriminator output for the noise cancellation.

U.S. Pat. No. 5,036,299, issued Jul. 16, 1991 to Dick et al., the contents of which are incorporated herein by reference in their entirety, teaches several modifications to the cavity discriminator approach. First, Dick et al. teaches the use of a cavity discriminator to clean up an external noisy oscillator—a system denoted as STALO (Stabilized Local Oscillator). A similar configuration for cleaning up a noisy DRO using the cavity was already disclosed in the open literature (F. L. Walls, C. M. Felton, T. D. Martin, "High Spectral Purity X-Band Source," Proc. 1990 IEEE Freq. Cont. Symp., pps. 542–548, May 23, 1990). Second, Dick et al. teaches the use of almost critical coupling for signal into the cavity. This results in a high level of "carrier suppression" in which the power in the center frequency of the external oscillator is reduced, while its noise is not. Third, Dick et al. claims the use of an RF amplifier to amplify the carrier-suppressed reflected signal. Improvements in the cavity discriminator performance resulting from Dick et al. inventions are twofold. First, the amplification of the reflected signal within the discriminator results in the increase of the discriminator gain. Second, carrier suppression of the reflected signal results in reduction of multiplicative noise introduced by this same amplifier, and the introduction of the amplifier before a phase-detector mixer resulted in overcoming the mixer noise, a heretofore key noise-limiting component. Thus, the invention of Dick et al. results in reduction of the effective noise due to components.

U.S. Pat. No. 5,841,322, issued Nov. 24, 1998 to Ivanov et al., the contents of which are incorporated herein by reference in their entirety, teaches a method for increasing carrier suppression using an "interferometer" arm of the reflected signal from the cavity to vectorially add to the reflected signal (using a power combiner) a portion of the input signal fed into the cavity with the same amplitude as the reflected signal, but whose phase has been shifted by 180° with respect to it. Ivanov teaches a very high level of carrier suppression can be achieved with fine amplitude and phase adjustments. Also, together with the carrier suppression already obtained by near critical coupling, it is possible to achieve a level of almost no carrier as seen by the Dick et al. amplifier of prior art. Hence, Ivanov et al. teach further elimination of its multiplicative noise, which is predominantly "flicker," a highly undesirable noise type. Using an RF amplifier with very low thermal noise and a very high gain, it is possible to then achieve both the desirable conditions of increased discriminator gain and lowered flicker noise in the phase detection.

Thus, prior art is focused on reducing the effects of noise in non-discriminator components comprising the phase-noise detector in the oscillator, which typically are mixers, amplifiers, combiners, and the like. That is, several novel techniques have been devised to reduce the close in noise of microwave oscillators (Galani et al., 1985; Galani et al., 1991; Dick et al., 1991 and Ivanov et al., 1998). In essence, all the foregoing techniques utilize a microwave cavity with high Q factor. They teach that this cavity can be used in two ways:

a) as a Direct feedback oscillator, where the cavity is integrated as a part of the feedback loop of the microwave oscillator; and

b) as a Cavity Stabilized Oscillator, where the cavity is used to clean up an external noisy oscillator locked to it.

In either case (a) or (b), the role of the cavity is that of a frequency discriminator, which converts noise-induced frequency fluctuations from components ahead of the discriminator into corresponding phase variations of a signal reflected from it. A double balanced mixer, used as a phase detector, further converts the phase to voltage fluctuations, which are then suitably amplified and fed back to the oscillator to correct its frequency fluctuations. It is important to note that this phase detection noise is not cleaned up by the discriminator and ideally sets the noise floor. This noise is the focus of ongoing efforts to reduce oscillator noise.

In the case of the Direct Feedback Oscillator (a), the feedback is used to modulate the oscillator loop phase shift using a voltage controlled phase shifter. In the case of the Cavity Stabilized Oscillator (b), the feedback modulates the oscillator frequency using a voltage controlled tuning port of the oscillator.