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Bistable microwave oscillator with magnetostatic wave signal-to-noise enhancer in the feedback loop

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A microwave feedback oscillator with a saturable amplifier and a nonlinear magnetostatic spin wave signal-to-noise enhancer device in the feedback loop is described. The oscillator has bistable behavior and can be turned on with short low power microwave pulses.

Introduction: Microwave feedback oscillators with an amplifier and a magnetostatic wave (MSW) transmission line in the feedback loop can be tuned electronically over a wide frequency range [1] and have a low phase noise [2]. This paper describes a bistable microwave feedback oscillator design that utilizes a saturable amplifier and a nonlinear MSW transmission line in the feedback loop.

Oscillator design: A diagram of the oscillator feedback loop is shown in Fig. 1. It consists of a microwave GaAs amplifier with a low power gain G and saturation at high power, input and output directional couplers, an nonlinear MSW signal-to-noise enhancer (S/N-E) transmission line [3] with a power dependent insertion loss L, a narrow band microwave yttrium iron garnet filter (YIG-F), and a variable attenuator of loss factor A. The low level gain G was 31 dB and the amplifier output saturation power was 0.5 W in a 2.5–6 GHz frequency band. The filter had a center frequency $f = 3.23$ GHz and a 40 MHz passband. The S/N-E line consisted of a 30 μm thick, in plane magnetized single crystal YIG film biased by a 310 Oe field parallel to a 12 mm long 50 μm wide microstrip transducer line on top of the film. The S/N-E transmission insertion loss L vs. input power is shown in Fig. 2. Within the 3–3.4 GHz operational frequency band, the S/N-E had an insertion loss L of 23 dB for input powers less than 1 mW and a low insertion loss of 12 dB for input powers above 400 mW.

Operation: Figure 3 shows several schematic power response curves for the power P_E at output point E for the S/N-E line as a function of the power P_I at the amplifier input point I. Curve GL shows the combined amplifier and S/N-E open loop response from point I to point E. Region I is the low power linear response regime of the amplifier and the high insertion loss regime for the S/N-E line. In region II, the amplifier is still in the linear regime, while the S/N-E line has a reduced insertion loss. In region III, the amplifier output saturates and the S/N-E insertion loss is low. As will be apparent shortly, this power dependent response leads to bistable operation. The straight line response curves in Fig. 3 show the linear open loop response through the attenuator from point E to point I for three values of the attenuation factor A, (A_a, A_b, and A_c). Because the graph displays P_E vs. P_I, the slopes of the lines scale with the attenuation factor. For curve A_a, the attenuation is high, the E-to-I loss is larger than the I-to-E gain and there can be no oscillation. Spontaneous oscillation is not possible until the attenuation drops down below some low value indicated by the A_b curve. At this point, the E-to-I loss falls below the I-to-E gain at low power levels and the oscillation begins. For operation at A_b, the amplifier input power then moves to a relatively high value indicated by P_b. If A is reduced further, the output power remains relatively constant because of the amplifier saturation. Once the oscillation is established, the attenuation can then be increased to values well above A_b without a significant loss of power. As the attenuation is increased to the point indicated by curve A_c, P_I will drop to a value P_c. At larger values of A, the oscillation will cease. Bistable operation will occur for A-values between A_b and A_c and output powers between $P_E(P_b)$ and $P_E(P_c)$.

Experimental results: Fig. 4 shows the measured dependence of the oscillator output power P_{out} vs. attenuation A for the device described above. The right and up pointing arrows and the left and down pointing arrows show the changes in output power for decreasing and increasing values of the attenuation, respectively. The bistable points for the onset and shut off of the oscillation are at 1 dB and 8 dB, respectively. The bistable operation makes it possible to initiate oscillation by the application of an external microwave signal with the device in a quiescent state and A set in the 1 dB and 8 dB range.. Microwave pulses at 3.2 GHz, and with widths above 25 ns and powers above 1.8 mW, could be applied at the input P_{in} point in Fig. 1 to switch on the oscillator. The minimum pulse energy required to start the oscillations was about 5×10^{-11} J. In order then to turn the oscillation off, it was necessary to decrease the attenuation below the cut-off at $A = -8$ dB.

Conclusion: Bistable operation of a microwave oscillator containing a MSW nonlinear transmission line and a saturable amplifier in the feedback loop has been demonstrated. The output power depends on the history of the system and the setting of the attenuator in the feedback loop. The oscillator can be turned on with short external microwave pulses.

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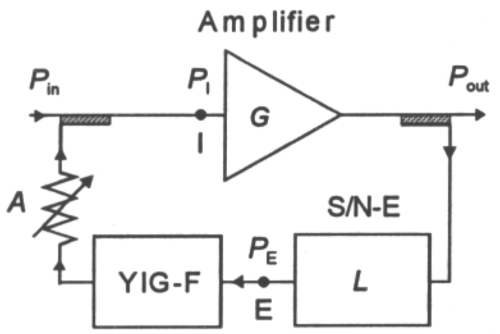

Fig. 1. Diagram of oscillator feedback loop configuration.

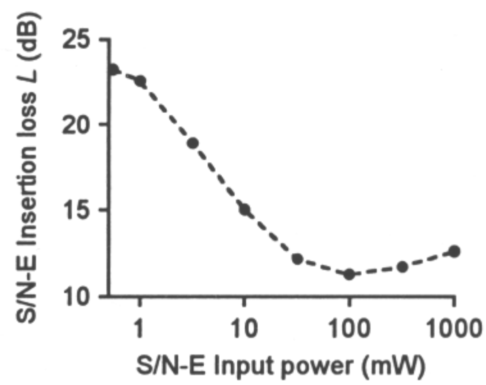

Fig. 2. Characteristic transmission of S/N-E nonlinear transmission line.

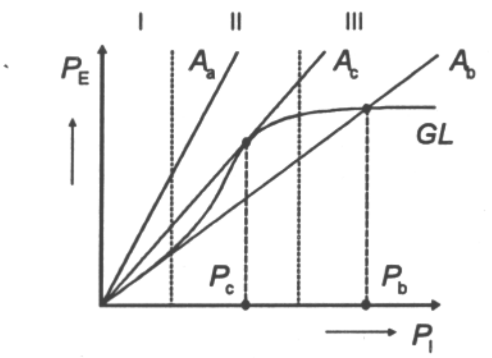

Fig. 3. Power response curves of P_E vs. P_I for the amplifier and S/N-E part of the feedback loop (GL) and the attenuator part of the loop (A_a, A_b, and A_c).

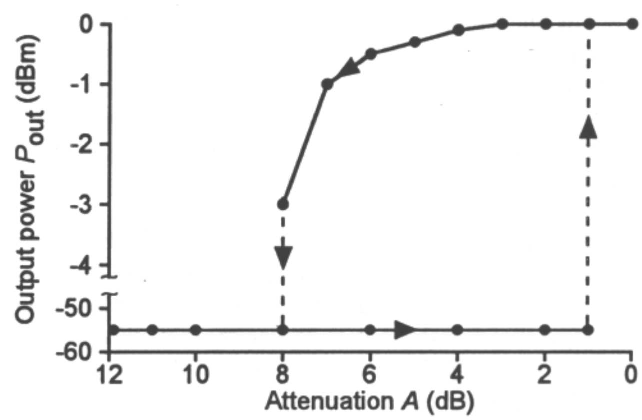

Fig. 4. Oscillator output power as a function of the attenuation A for a cycle of increasing and then decreasing A.