VI-7 A HIGH SPEED BINARY PULSE REGENERATOR IN MICROWAVE FREQUENCIES

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Introduction

In a long-distance communication system by means of pulse code modulation, repeaters are set along the route of transmission in order to regenerate pulses which have been degraded by several types of distortion due to noise, bandwidth limitations and other effects.

Recently, a bit rate of PCM shows a extending tendency to much higher, for the transmission of television, picturephone and other broad band signals. Therefore, functions of the pulse regenerator are required to handle higher bit rate signals for the previously mentioned uses.

The methods of regeneration and the experiments described here are concerned with regenerating high speed PCM-AM pulses directly at 10.6 GHz, using a hysteresis characteristic and a locking oscillation characteristic of an Esaki-diode oscillator.

Method of the regeneration

In an Esaki-diode oscillator which has a high-Q resonator, we can obtain a typical characteristic between the oscillation power and the dc bias voltage which is supplied to the diode, as shown in the left part of Figure 1. Bias voltages of V_x and V_z are near the peak voltage and the valley voltage of a V-I characteristic of the Esaki-diode respectively. The broken line of curve C shows the hysteresis region obtained theoretically. Varying the bias voltage from zero in a positive direction, oscillation is begun at the bias voltage V_x and that is stopped suddenly at V_z. However, when the bias voltage is varied towards zero from a more positive voltage than V_z, the oscillation occurs quickly at V_y and stops at V_x; that is, in the region between V_y and V_z, for example at V_r, it is possible for two states to exist, i.e., that the oscillation exists or does not.

Under the condition that the oscillation does not exist in the region between V_y and V_z for instance at V_r, this oscillator has an amplification characteristic for a small power supplied into the oscillator circuit and whose frequency is near the free-running frequency of the oscillator. And if the amplified power level exceeds the level of P_r, then the oscillation steps up quickly to the level of P_o in Figure 1, and the oscillation frequency is locked to the injected signal as well known. Thus, it is possible to change the state from non-oscillating to oscillating by injecting the small power to the oscillator, within the hysteresis region. The pulse regenerator is based on this characteristic. The regeneration of pulses consists of two functions. The first function is that of removing amplitude distortion, the second is that of restoring each pulse to its proper time.

In the Esaki-diode oscillator, which has the above mentioned characteristic, the timing pulse train of PCM controls the bias voltage of the diode from the voltage V_r to a voltage more positive than V_z, as shown in the right part of Fig. 1. The oscillation cannot occur under this condition. However, the degraded PCM signals, whose carrier frequency is near the free-running oscillation frequency at the bias voltage V_r, are supplied to the oscillator, then they are amplified and their amplified power levels exceed the level of P_r at the synchronized times when the voltages of biased timing pulses are V_r respectively; the oscillations, whose frequency is locked to the injected carrier frequency, then step up quickly, but are stopped by the biased timing pulses which move to the voltage more positive than V_z. The modeled envelopes of input signal and these of output signal are shown in Fig. 1.

Experimental results

In the experiments, the wave-guide type oscillator (Fig. 2) was used at the regenerator. And the Esaki-diode mounted in the oscillator was made from an n-type germanium crystal and its electrical characteristics were f_{ro} of 35 GHz and I_p of 1.8 mA, etc.

Characteristics of the oscillator are shown in Figs. 3 and 4. Fig. 3 shows the characteristic of the oscillation power and the oscillation frequency vs. the bias voltage of the diode. When a signal is injected into the oscillator circuit, the oscillation frequency is pulled toward the signal frequency. Removal of the injecting signal and measurement of the frequency difference between the free-running oscillator and injection signal of 10.6 GHz results in data for Fig. 4. Locking is depend upon oscillator circuit parameters. In this case, the curves show that lock was observed down to an injection ratio of 60 dB.

A block diagram of the experimental setup for experiments of pulse regeneration is shown in Fig. 2. As signal sources of a PCM system, a 110 Mb/s (7 bits) pulse pattern generator and a 220 Mb/s (12 bits) pulse pattern generator were used. The works were performed at a frequency of 10.6 GHz. The carrier was amplitude-modulated with a crystal diode modulator and was supplied to the pulse regenerator through a modeled transmission line which was constructed by a filter and an attenuator.

The characteristics between input level and output level of this regenerator are shown in Fig. 5. The curve A shows characteristic of the regenerator in the case of the lower bit rate less than 10 Mb/s, the curve B shows that of 110 Mb/s and the curve C shows that of 220 Mb/s. About the curve A, the complete regeneration characteristic was for the most part obtained. However, the higher the bit rate became, the more the characteristic became to that of like the partial regeneration.

In the case that the bit rate was 220 Mb/s, the output power of the regenerator was lower than that in the case of working at the lower bit rate; that was, concerning with the rise time of the oscillation, the oscillator became hard to respond to the higher bit rate. However, in the case of 400 Mb/s bit rate, the output power of the regnerator is lower than that in the case of working at the lower bit rate by only 2 dB, and it was not hard to obtain the regenerating characteristic.

The oscillograms of Fig. 6 show the typical input signals and the output signals detected with a crystal diode, in the following conditions.

	(a)		(b)	
Bit Rate	100 Mb/s		220 Mb/s	
Pattern	1101110		110000000000	
	Input	Output	Input	Output
Peak Power	−40 dBm	−17 dBm	−40 dBm	−18 dBm
Modulation Index	10 dB	20 dB	10 dB	20 dB

Conclusion

Merits of this regnerator are,

1) regenerating directly at microwave frequencies,
2) working with a small input level and having a gain,
3) responding to a high bit rate, etc.

And by considering the characteristics of an Esaki-diode and a construction of an oscillator, we will be able to obtain a higher speed and more reliable pulse regenerator.

The most obvious application is for a repeater in millimeter-wave communication systems using a circular wave guide transmission line.

References

1. O.E. DeLange, "Experiments on the regeneration of binary microwave pulses", Bell Sys. Tech. J., vol. 35, pp. 67-90, Jan. 1956.
2. M. Sugiyama, Y. Matsuo and A. Saeki, "Experiments on binary microwave pulse regeneration", Proc. IEEE (Correspondence), vol. 53, pp. 550-551, May 1965.
3. M. Sugiyama, Y. Matsuo and A. Saeki, "A new microwave pulse regenerator", Proc. IEEE (Letters) vol. 54, pp. 433-434, March 1966.

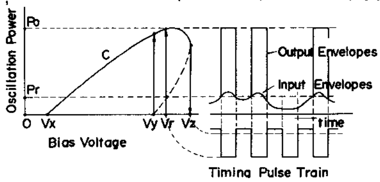


FIG. 1 - Typical hysteresis characteristic of the Esaki-diode oscillator power vs. the bias voltage of an Esaki-diode, and the principle of the binary microwave pulse regeneration using this characteristic

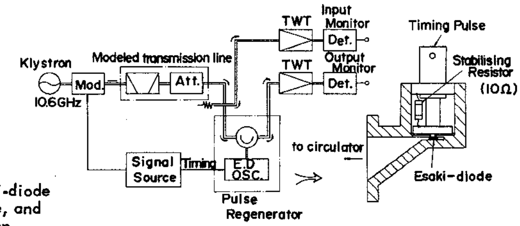


FIG. 2 - Block diagram of the basic experimental setup and construction of the Esaki-diode oscillator

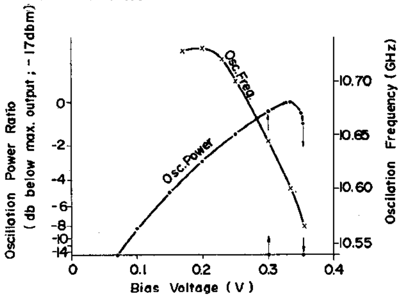


FIG. 3 - Oscillation power and oscillation frequency vs. the bias voltage

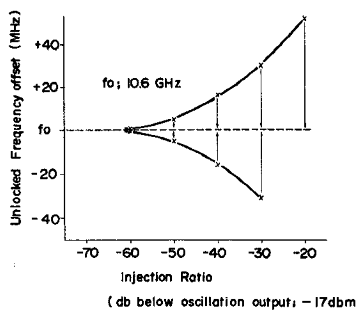


FIG. 4 - Locking characteristic of the Esaki-diode oscillator

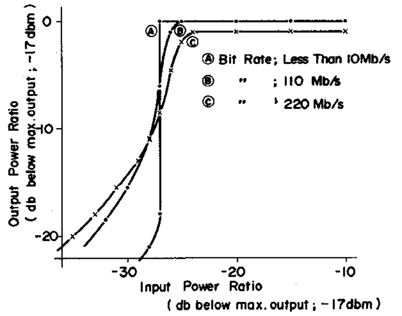
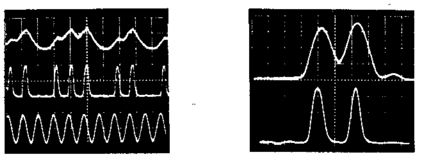


FIG. 5 - Input-output characteristics of the regenerator employed in these experiments



(a) Bit rate ; 110 Mb/s
(10 ns/major div.)
Top : Detected input signals
Middle : Detected output signals
Bottom : Timing wave

(b) Bit rate ; 220 Mb/s
(2 ns/major div.)
Top : Detected input signals
Bottom : Detected output signals

FIG. 6 - Effects of regeneration