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1.2 Gbit/s PSEUDO RANDOM PULSE GENERATOR USING MULTIPLEXING WITH GaAs MESFET GATES

Carsten Hede*

ABSTRACT

A 1.2 Gbit/s RZ pseudo random bit generator using multiplexing of six 200 Mbit/s channels, and a GaAs-MESFET gate circuit which exhibits both high speed and simplicity are presented.

As a new contribution to the treatment of pseudo random sequences it is shown how the autocorrelation function and the Fourier spectrum of a sequence obtained by multiplexing are distorted. These functions may be shaped to a desired form by proper choice of mutual delays of sequences contributing to the multiplexing.

1. INTRODUCTION

In many fields, such as optical communication, radar technique, and digital data processing, there is an increasing need for subnano second electronics. At present much progress is achieved in gigabit/s logic and many different approaches are under investigation [1].

A useful tool in fast electronics is the pseudo random pulse generator where the bit sequence is generated in a shift register with appropriate feed back connections. Pseudo random sequences generated in this way have suitable properties for testing and evaluation of communication systems [2].

In the laboratory the integrated technique has entered the sub-nano second region [3], but such fast circuits are not yet commercially available. Consequently, pseudo random generators for applications in the gigabit range cannot be built using standard integrated elements. One way to overcome this problem is to multiplex a number of pseudo random sequences generated at a lower frequency. The drawback of this technique is that the autocorrelation and spectral properties of a multiplexed sequence is somewhat degraded compared to those of the individual shift register sequences.

The technique of multiplexing sequences has been demonstrated using bipolar transistors [4] and step recovery diodes [5], [6]. This paper presents a new and very simple approach using a hybrid GaAs-MESFET gate circuit which may be regarded as a hybrid, analog version of the gates used in integrated techniques [7]. The GaAs-MESFET is a very fast component and offers simplicity in circuitry compared to, for instance, bipolar transistors.

A bit rate of 1.2 Gbit/s is achieved by multiplexing six 200 Mbit/s bit streams.

The paper will describe first the total system, then the FET-gate. Finally, the autocorrelation and spectral properties of multiplexed sequences will be treated.

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2. 1.2 Gbit/s SEQUENCE GENERATOR

2.1 BLOCK DIAGRAM

Fig. 1: Block diagram of 1.2 Gbit/s pseudo random pulse generator.

NRZ signal modulates a 400 MHz narrow pulse stream obtained from the 200 MHz clock signal of the shift register generator. This clock signal is frequency doubled, amplified, and converted into a narrow pulse stream using step recovery diodes.

Fig. 2: ECL OR combiner.

Fig. 3 shows a typical output from the generator. The GaAs MESFETs used, had saturation currents below 15 mA. Using transistors with higher saturation currents a cleaner output signal can be obtained because the Schottky-barrier diodes in the final OR-gate working into 50Ω will at a higher voltage level be closer to ideal diodes.

Fig. 3: Output from 1.2 Gbit/s sequence generator.

2.2 GaAs-MESFET GATE CIRCUIT

The GaAs-MESFET has earlier been investigated for high speed switching [7] [8]. Performance at 4 GHz has been demonstrated [3]. The extreme speed offered by this component makes it very simple to apply in circuits at least in the lower Gbit/s range.

The GaAs-MESFET gate circuit presented here consisted of three single gates. Fig. 4 shows the simple configuration of a single FET-gate.

Fig. 4: GaAs-MESFET AND-gate.

Fig. 5: Performance of a GaAs-MESFET AND-gate.

- (a) 400 MHz pulse input.
- (b) 400 Mbit/s NRZ logic input.
- (c) Modulated pulse output.

Two MESFETs are coupled in parallel and are driven in the saturation region. They act as nearly ideal current sources. Thus, the output voltage is the inverted sum of the two input voltages. Fig. 5 shows a test of a MESFET gate. The low shifted pulses in the output signal are removed by the final Schottky-barrier OR-gate.

The FETs used were chips bonded directly into a microstrip circuit.

3. AUTOCORRELATION AND SPECTRA OF MULTIPLEXED SEQUENCES

In this work, multiplexing is performed as an addition of time signals as illustrated in fig. 6 for the case of three sequences. It will be assumed that the sequences contributing to the multiplexing are identical, i.e. are mutually delayed versions of the same sequence.

Fig. 6: Multiplexing of sequences.

3.1 AUTOCORRELATION

The digital autocorrelation function, $\rho(i)$ [2], for a maximal length shift register sequence is illustrated in fig. 7. It has the value $-1/N$ except of course for $i = pN$, where p is an integer and N is the bit sequence length.

Consider the multiplexing of two sequences. The mutual time shift must be an odd number of half clock periods; let it be $(2p+1)\frac{\Delta T}{2}$, where ΔT is the clock period. For the multiplexed sequence, $\rho(i)$ will have the period $2N$ and assume the same values as for a single sequence except for a few special i -values.

Fig. 7: Digital autocorrelation function of maximal length sequence.

For $i = 2p+1$, the calculation of $\rho(i)$ will partly be a correlation of the original sequence with itself. The same is true for $i = 2N-2p-1$. Thus $\rho(2p+1)$ and $\rho(2N-2p-1)$ will be large and the periodicity implies two extra peaks in each period of the autocorrelation function. This is illustrated in fig. 8.

If three or more sequences are multiplexed,

more $\rho(i)$'s will be different from $-\frac{1}{N}$. Some of these special i -values may coincide. Fig. 9 illustrates the case of multiplexing three sequences where two pairs of special i -values coincide.

Fig. 8: Autocorrelation function for multiplexing of two sequences.

The autocorrelation function of a multiplexed sequence has a slightly smaller resemblance to that of a truly random sequence than does the autocorrelation function of a single shift register sequence. The actual pattern of degradation is a function of sequence delays and may be shaped by proper choice of these delays.

Fig. 9: Autocorrelation function for multiplexing three sequences.

3.2 SPECTRUM

The Fourier power spectrum of a maximal length shift register sequence is similar to that of a truly random sequence. Both have the same envelope and possibly single larger components at the clock frequency and its harmonics. However, due to the signal periodicity the shift register sequence spectrum is discrete. The amplitude spectrum envelope and discrete components of sequence 1 in fig. 6 is shown in fig. 10. $F(n)$ is the component at frequency n/T ; T is the sequence period.

Fig. 10: Fourier spectrum of pseudo random sequence.

If three such sequences are multiplexed as illustrated in fig. 6, with delays of sequence 2 and sequence 3 with respect to sequence 1 of $(3p_2+1)\frac{\Delta T}{3}$ and $(3p_3+2)\frac{\Delta T}{3}$ respectively, then the Fourier spectrum of the multiplexed sequence is given by

$$F_{sq}(n) = F(n) \left[1 + e^{-jn \frac{2\pi}{T} (3p_2+1) \frac{\Delta T}{3}} + e^{-jn \frac{2\pi}{T} (3p_3+2) \frac{\Delta T}{3}} \right] \quad (1)$$

That is, the spectrum is distorted due to the multiplexing. Fig. 11 (a+b) shows examples of distorted spectra.

Fig. 11: Spectra distorted by multiplexing. (a) $p_2 = 0, p_3 = 3$
(b) $p_2 = 3, p_3 = 1$

The distortion is of course dependent on the actual sequence delays chosen, so to some extent the spectrum envelope may be shaped to a desired form by proper choice of delays.

3.3 AUTOCORRELATION AND SPECTRUM OF 1.2 Gbit/s SEQUENCE

The mutual delays of the six channels of the 1.2 Gbit/s generator were chosen so that the autocorrelation function had no peaks near 0 and no

Fig. 12: Calculated sequence spectrum.

Fig. 13: Measured sequence spectrum.

peak coincidences. With these restrictions the spectrum was shaped to the closest resemblance of a truly random sequence spectrum. Fig. 12 shows the calculated spectrum assuming triangular pulses and Fig. 13 shows the measured spectrum.

To some extent the two spectra are similar. Of course the measured spectrum is narrower than the theoretical one. The presence of the 200 MHz clock frequency and its harmonics in the measured spectrum (these lines are not drawn to scale) is probably due to a not perfectly precise realization of the delays. The calculated spectrum shows that these components should be extinguished.

4. CONCLUSION

A 1.2 Gbit/s pseudo random pulse generator using multiplex of six 200 Mbit/s channels has been presented. A new, simple and very fast GaAs-MESFET gate circuit has been shown.

The autocorrelation and spectral consequences of multiplexing have been discussed. The importance of choosing proper sequence delays when designing sequence generators using multiplexing has been demonstrated.

Due to the very high speed switching characteristics of GaAs-MESFETs the gate circuit presented should be applicable to higher bit rates than demonstrated here. The real advantage of MESFETs is perhaps first obtained in the integrated technique. But here GaAs MESFETs are somewhat inconvenient because of the level shift from gate to drain [7]. However, this difficulty can be overcome by the use of other transistors, for instance normally-off GaAs-MESFETs.

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