Broadband Low Power Transmitter in SiGe Technology Based on Maximum Length Sequences

Breitbandiger Low Power-Sender in SiGe-Technologie auf Basis von Maximalfolgen

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M.Sc. Ahmed Gharib Radwan

aus Kairo, Ägypten

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Berichte aus der Elektronik

Ahmed Gharib Radwan

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Abstract

This work presents a broadband transmitter of high versatility, where the spectral characteristics of the transmitted signal can be adapted for different applications. The transmitter is based on pseudo-random bit sequences (PRBS), capable of generating a sequence of a bit rate up to 80 Gb/s. Moreover, the transmitter is equipped with a broadband double side-band mixer, which is capable of shifting the generated spectrum to the frequency range of interest, ranging from 10 GHz up to 60 GHz.

For the implementation of a broadband and low power transmitter, two novel broadband circuit techniques were developed and analyzed. The introduced techniques were employed in all designed components. Hence, a broadband performance with a low power consumption, compared to state of the art designs, is achieved.

Several components were designed in the scope of this work, including baluns, a PRBS generator, broadband amplifiers and a broadband double band mixer.

Two baluns were designed: a broadband low-power active balun operating from near DC-frequencies up to 70 GHz and a passive Marchand balun operating from 15 GHz up to 80 GHz.

A 2^{11}-1, 80 Gb/s PRBS generator, employing parallel architecture is presented. The generator is optimized to provide a high bit rate as well as a long sequence length without any need of inductive peaking for a lower power consumption, compared to PRBS generators reported in literature. The PRBS generator consists of two parallel complementary rows of linear feedback shift registers (LFSR), operating up to 40 Gb/s. The generated PRBS from each row are multiplexed to provide a bit-rate of double the clock frequency, reaching up to 80 Gb/s. The clock distribution network was carefully optimized for a reduced amplitude and phase error to push the boundaries of the maximum achievable bit-rate. The PRBS generator is capable of generating bit-rates ranging from 10 Gb/s up to 80 Gb/s, with a power consumption of 576 mW to 1 W.

Differential multi-stage amplifiers were built within the clock network for clock signal formation and at the transmitter output stage to boost the signal power prior to transmission. Moreover, a similar amplifier, but of different specifications, was designed to investigate and demonstrate the potential enhancements that the two novel bandwidth (BW) extension techniques can provide. The amplifier could achieve a gain of 54 dB and a 3-dB BW of 25 GHz, resulting in a gain-BW product (GBP) of 12.5 THz, with a power consumption of 180 mW from a 3.3 V supply, which outperforms any other state of the art amplifier reported in literature.

The transmitter was built into a radar setup to demonstrate its functionality, expected capabilities and potential applications.

Kurzfassung

Diese Arbeit stellt einen breitbandigen Sender mit hoher Vielseitigkeit in der Anwendung vor. Die Spektraleigenschaften des gesendeten Signals können an unterschiedliche Anwendungen adaptiert werden. Der Sender basiert auf Pseudozufalls-Bitsequenzen (PZBS) und kann Bitraten bis zu 80 Gb/s erzeugen. Außerdem ist der Sender mit einem breitbandigen Zweiseitenbandmischer ausgerüstet, welcher das erzeugte Spektrum in einen Frequenzbereich von 10 GHz bis 60 GHz umsetzen kann.

Für die Implementierung eines breitbandigen Senders mit geringem Stromverbrauch wurden zwei neuartige breitbandige Schaltungstechniken entwickelt und analysiert. Es konnte ein Betrieb mit hoher Bandbreite und niedrigem Stromverbrauch im Vergleich zu anderen modernen Entwürfen demonstriert werden. Mehrere Komponenten wurden im Rahmen dieser Arbeit entworfen wie beispielsweise Baluns, ein PZBS-Generator, breitbandige Verstärker und ein Zweiseitenbandmischer.

Zwei Baluns wurden realisiert: eine breitbandige Ausführung mit niedrigem Stromverbrauch für den Betrieb im Frequenzbereich von DC bis 70 GHz sowie ein passiver Marchand-Balun für den Bereich von 15 GHz bis 80 GHz. Der aktive Balun hat eine Leistungsaufnahme von 29,7 mW.

Ein 2^{11}-1, 80 Gb/s PZBS-Generator, der eine Parallelarchitektur verwendet, wird vorgestellt. Der Generator ist dafür optimiert, eine höhere Bitrate mit gleichzeitig längerer Sequenz bereitzustellen. Hierzu wird keine induktive Verstärkungsanhebung benötigt, was einen geringen Stromverbrauch im Vergleich mit anderen PZBS-Generatoren in der Literatur ermöglicht. Der PZBS-Generator besteht aus zwei komplementären, linear rückgekoppelten Schieberegister-Zeilen, die mit bis zu 40 Gb/s betrieben werden können. Die erzeugte Sequenz jeder Zeile wird gemultiplext, um die doppelte Bitrate von bis zu 80 Gb/s zu erhalten. Das Taktverteilnetz ist sorgfälltig optimiert worden, um geringe Amplitude- und Phasenfehler gewährleisten zu können. Dies ist erforderlich um die maximal mögliche Bitrate zu erhöhen. Der PZBS-Generator kann bei einer Leistungsaufnahme von 576 mW bis 1 W Bitraten von 10 Gb/s bis 80 Gb/s erzeugen.

Zur Erhöhung der Sendeleistung wurde im realisierten Sender ein differentielle dreistufiger Verstärker implementiert. Außerdem ist ein Verstärker mit abweichenden Spezifikationen entworfen worden, um die potenziellen Vorteile, die zwei neuartige breitbandige Schaltungstechniken bieten, untersuchen und demonstrieren zu können. Der Verstärker kann 54 dB Verstärkung bei 25 GHz Bandbreite bereitstellen. Dies entspricht einem Verstärkungs-Bandbreite-Produkt von 12,5 THz, bei einer Leistungsaufnahme von 180 mW. Die erreichten Parameter stellen im Vergleich zu anderen aktuellen Entwürfen

hervorragende Werte dar.

Schließlich wurde die Baugruppe in einen Radaraufbau integriert, um die Funktionalität, die erwartete Leistungsfähigkeit und potenzielle Anwendungen zu untersuchen.

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List of Abbreviations

AB ..... Amplitude balance
AC ..... Alternating current
ACF ..... Auto-correlation function
BJT ..... Bipolar junction transistor
BW ..... Bandwidth
CB ..... Common base
CC ..... Common collector
CCC ..... Capacitively controlled cross-coupled
CCR ..... Common-collector resistive feedback
CE ..... Common emitter
CG ..... Conversion gain
CM ..... Common-mode
CML ..... Current-mode logic
CMOS ..... Complementary MOSFET
CMRR ..... Common mode rejection ratio
CrC ..... Cross-correlated
CW ..... Continuous wave
DC ..... Direct current
DSP ..... Digital signal processing
E^2CL ..... Double emitter-coupled logic
ECL ..... Emitter-coupled logic
EF ..... Emitter follower
EM ..... Electromagnetic
FOM ..... Figure of merit
FWHM ..... Full-width-half-magnitude
GBP ..... Gain-bandwidth-product
GD ..... Group delay
I/Q ..... Inphase/Quadrature phase
KCL ..... Kirchhoff current loop
KVL ..... Kirchhoff voltage loop
LFSR ..... Linear feedback shift register
LO ..... Local oscillator
LPF ..... Low-pass filter
LSB ..... Lower-side band

MLS ..... Maximum length sequence
NF ..... Noise figure
PB ..... Phase balance
PNCW ..... Pseudo-Noise Modulated Continuous-Wave
PRBS ..... Pseudo random bit sequence
PRF ..... Pulse repetition frequency
PRT ..... Pulse repitition time
PSD ..... Power spectral density
Radar ..... Radio detection and range
Rx ..... Receiver
SiGe ..... Silicon-Germanium
SNR ..... Signal to noise ratio
TAS ..... Transadmittance
TF ..... Transfer function
TIS ..... Transimpedance
TL ..... Transmission line
TRx ..... Transceiver
Tx ..... Transmitter
USB ..... Upper-side band

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