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A DOPPLER RADAR SENSOR IN INTEGRATED FIN-LINE TECHNIQUE

L. SZABO
Standard Elektrik Lorenz AG
Hellmuth-Hirth-Str. 42
D-7000 Stuttgart 40
GERMANY

E. JENSEN
Institut für Hochfrequenztechnik
Technische Universität Braunschweig
D-3300 Braunschweig
GERMANY

Abstract

An experimental 35 GHz FSK-CW Radar Sensor is described. A low cost integrated FIN-line structure performs a fast switching VCO, hybrid junction, reflection type modulator and down converter. A single oscillator with a high Q varactor acts as both, transmitter source and receiver local oscillator. The integrated frontend with IF preamplifier has a size of 5,0 x 5,5 x 1,8 cm^3. Its features are low cost, small size, a minimum number of components for a minimum range of 70 m with $1m^2$ effectiv radar cross section targets.

Introduction

The system solution using a Frequency Shift Keyed Continous Wave Radar technique has the following main advantages:

- one antenna, because isolation between receive and transmit functions is not necessary
- no need for non-reciprocal components (isolator, circulator)
- only one oscillator is used
- minimization of semiconductor elements in the mm-wave range
- integration using FIN-line circuits
- low cost, minimum size approach.

Configuration

The block diagram is shown in Fig. 1. It shall be read in conjunction with the signal waveforms at various ports which are d splayed in Fig. 2. The sensor frontend consists of a Gunn-Diode VCO, a 3 dB-hybrid, a balanced mixer and the IF preamplifier with STC (Sensitivity Time Control). Transmit and local oscillator power for the mixer are generated in the VCO. The transmit frequency is 150 MHz higher than the LO frequency. It is fed to a 3 dB-hybrid whose symmetric ports are terminated with short circuits using biased mixer diodes to couple the transmit pulse with a width of 20 ns to the antenna. In the receive state the Gunn signal pumps the two Schottky diodes. The system now acts as a balanced mixer for the received signal which gets reflected from a target and which has a pulse width of about 20 ns and a frequency that corresponds to the transmit frequency plus doppler. The received signal will be down converted and amplified with the STC. The IF signal equals the difference of the two Gunn oscillator frequencies plus or minus the Doppler shift. The leading edges of the IF signals are modulated by the doppler shift if there is a time-dependent relative velocity between object and sensor. This velocity can be obtained from integrating over many received pulses if the transmit and receiver frequencies are stable enough.

The leading edge will be sampled and hold to a positive clamping value if the leading edge of the amplitude has a positive gradient and a negative value for a negative gradient. From the low-pass integrated output signal of the S/H block, the information on the Doppler shift can be derived.

Design

Technical points for the design of principal circuits are as follows:

(a) Voltage Controlled Oscillator

A main component for the system function is a fast switching VCO used as transmitter pulse source at frequency f_T and as receiver local oscillator at the frequency f_{LO}.

The repeatability of the on-tune condition of the two frequency states (f_T and f_{LO}) within narrow limits is a major specification. Frequency drift based on digital commands is a complex function of various elements of the VCO subsystem package as well as the interface variables. The frequency delay is controlled by video, thermal and semiconductor constraints.

An optimum for post runing drift was found afer detailed analysis of the VCO parameters in a definite range of Pulse Repetition Frequencies between 100 and 250 kHz, low duty cycle below 2 % and short pulses between 10 and 300 ns to minimize the frequency chirp in both frequency states. The optimum for the controlling values, also considering the system parameters, was derived as follows:

- distance measurement accuracy - transmit pulse length 20 ns
- minimal reaction time - pulse repetition frequency 150 kHz

The VCO is realized in a combined evanescent mode resonator FIN-line structure as described in more detail in /1/ and sketched in Fig. 3. The Gunn element has a nominal power of 100 mW tightly coupled to the high Q GaAs varactor (MA 46550). The electrical tuning bandwidth is about 4 %. The loaded Q-factor of the oscillator determined by a locking experiment is about 350.

The frequency characteristics of the VCO are measured with the use of a spectrum analyzer to observe the shift in spectral lines corresponding to the two alternating frequencies. The overall chirp integrated over more than ten minutes is less than 20 kHz for constant interface conditions. This value gives the capability to indicate a signal with pulse-to-pulse coherency and these test results are consistent with the system requirements. (Fig. 4)

(b) Switch-Mixer

A key component in the millimeter wave part of the radar sensor is the FIN-line switch-mixer which performs as transmit-receive selector and down-converter. The circuit consists of a 3 dB 90 degree hybrid. The full planar FIN-line structure using a configuration as described in /1/ has an insertion loss of less than 0,4 dB and a directivity of better than 30 dB in a 4 GHz band as shown in Fig. 5. The coupler is full symmetric in its electrical characteristics. The input reflection is below -20 dB. Due to the high directivity of the hybrid junction it is not necessary to insert an isolator at the output port of the oscillator structure to avoid frequency pulling effects.

Since efficient down-conversion requires a variable resistance as non-linear element, the switch-mixer must be equipped with Schottky diodes. Furthermore, if we combine a junction circuit with two Schottky diodes in order to establish a balanced mixer, we fulfill simultaneously the requirements of a reflection type switch. In the reverse biased state the diodes present nearly an open circuit so that the RF signal is reflected at the FIN-line short circuit behind the diode. The bias voltage is switched between two states at a rate given by the pulse repetition frequency.

The slot pattern of the switch-mixer mount for one arm is shown in Fig. 6. The impedance of the GaAs beam-lead Schottky diode (DMK 6606) has been measured around the operating frequency. Its reactive part is compensated by the short-circuited stub line behind the diode, while its real part is matched by the notch in front of the diode. The dimensions have been found by Computer Aided Design.

The performances of the switch-mixer are shown in Fig. 7 and Fig. 8.

Fig. 7 shows the frequency dependence of the return loss for the switching function in the two biasing states. The conversion loss and the noise figure performance of the balanced mixer is shown in Fig. 8.

Performance

Using a separation of 150 MHz between the two states of the VCO frequencies and an IF bandwidth of 70 MHz using a wide-band IF amplifier with a gain of 70 dB a signal-to-noise ratio of 13,5 dB is obtained. Other main specification values are shown in Fig. 10.

As substrat material RF-Duroid 5880 with 0,01 inch thickness is used.

Acknowledgement

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References

/1/ E. Kpodzo, L. Szabo, E. Jensen, K. Schuenemann Integrated FIN-line mm-Wave Transceiver Proc. 12th EuMc, Helsinki 1982, pp. 702-706

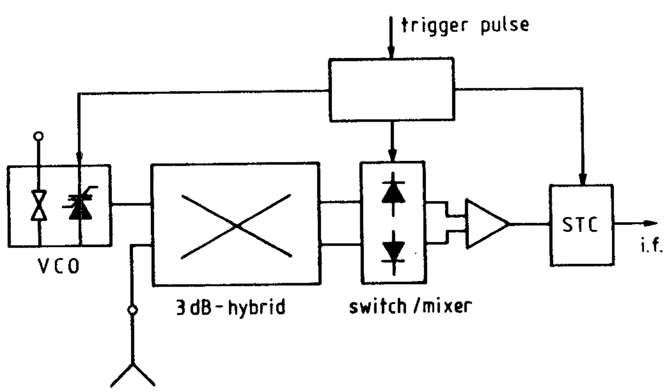

Fig. 1: Block diagram of the Doppler sensor

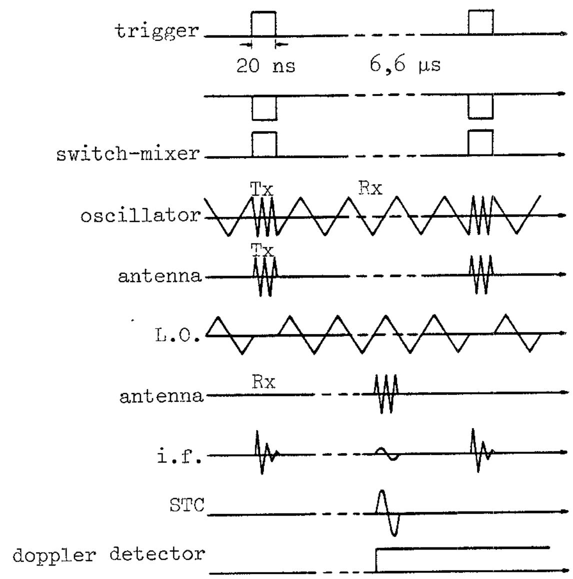

Fig. 2: Signal waveforms at various interfaces

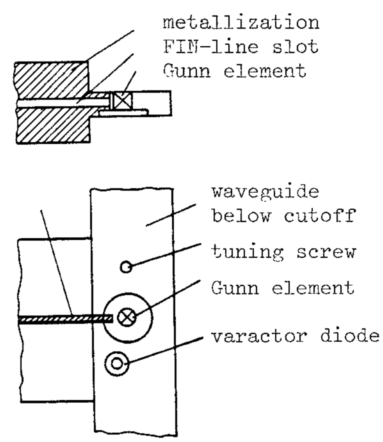

Fig. 3: Gunn oscillator with waveguide below cutoff mount and FIN-line output

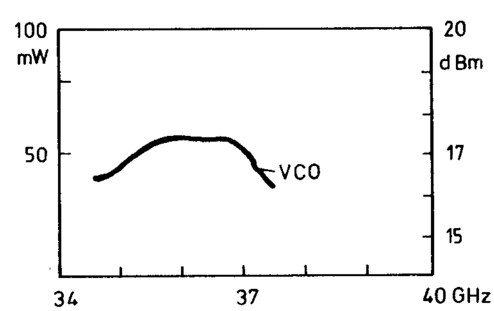

Fig. 4: Electrical tuning range of the FIN-cutoff oscillator

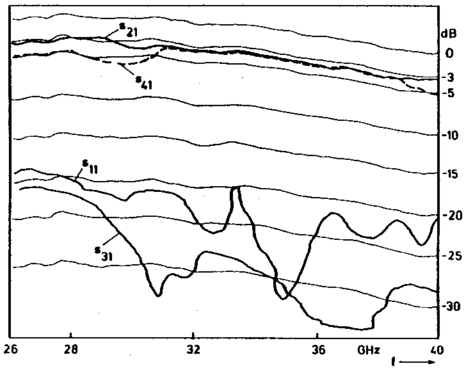

Fig. 5: Performance of the 3 dB-Hybrid

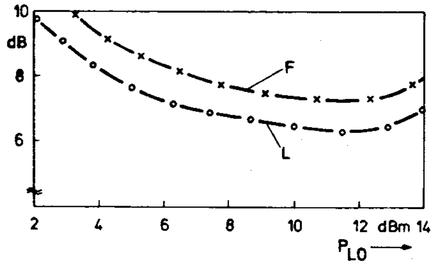

Fig. 8: Conversion loss L and noise figure F of the mixer versus Lo power level

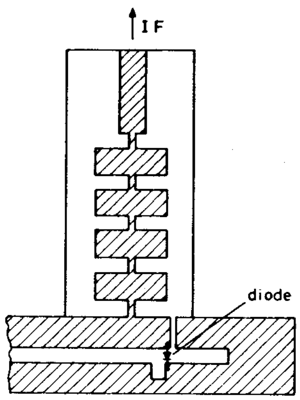

Fig. 6: Slot pattern of the mixer / modulator

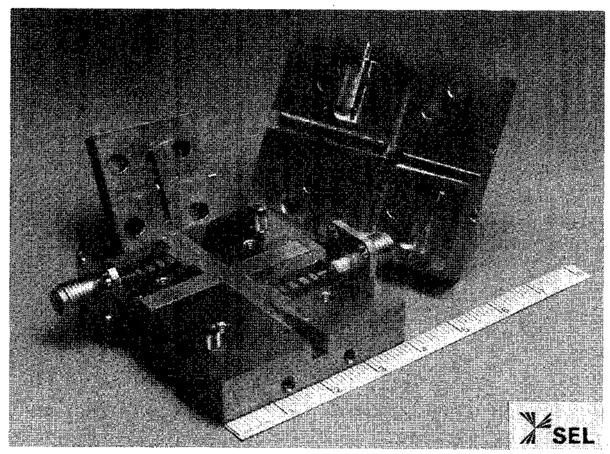

Fig. 9: Integrated Frontend Structure

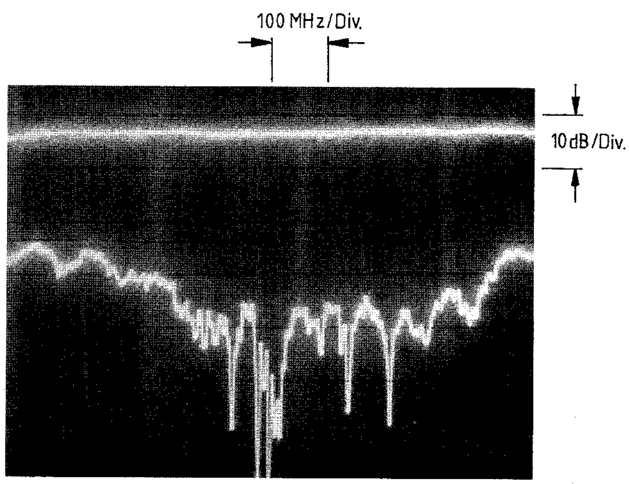

Fig. 7: Switching characteristics of the switch-mixer circuit

Transmit Frequency	f_T	36,0 GHz
Receive-LO-Frequency	f_{LO}	35,85 GHz
Pulse Length	τ	20 ns
Transmit Power	P_T	30 mW
Pulse Repetition Frequency	f_P	150 kHz
Antenna Gain	G_A	28 dB
Range Gates		24
Noise Figure	F	< 8 dB
Reaction Time		< 200 ms
Range (for $\sigma = 1m^2$)		> 70 m
Volume (Frontend)		$4 \times 5{,}5 \times 1{,}8$ cm^3

Fig. 10: FSK-CW Doppler Sensor Main Parameters