A Microstrip Low Cost, High Performance, Intruder Detector Radar

E. de los Reyes David - Antonio Elias Fusté
Miguel Ferrando Bataller - Ignasi Corbella Sanahuja
E.T.S.I.T. Barcelona
C/ Jordi Girona Salgado, s/n 08034 Barcelona (Spain)

Abstract. Doppler Radars operating as conventional intruder detectors at X band have been used in several security applications. However, almost all of them utilize heavy and bulky microwave subsystems in waveguide technology. This paper presents a new prototype on microstrip technology for a homodyne doppler radar system which exhibits excellent performance and low component cost.

Introduction

A radar intruder detector is based in the Doppler effect:

\[ f_d = \frac{2f_0}{c} \cdot \nu_r \]

where

- \( f_d \) = doppler frequency
- \( f_0 \) = emitter frequency
- \( c = 3.10^8 \text{ m/s} \)
- \( \nu_r \) = target radial speed

However, in this application the doppler frequency measurement is not essential. Only its detection is required in order to determine the intruder presence.

Microstrip technology provides several advantages over waveguide technology. On the other hand the performance reduction is very small. Size, weight and components cost are lower on microstrip.

The system presented in this communication has been developed on a plastic substrate (Cuclad 2.17).

Power Considerations

The radar equation reads as follows

\[ P_d = \frac{P_{OL} \cdot \frac{G^2}{4\pi^2} \cdot \lambda^2}{(4\pi)^2 R^2 L} \] (2)

where

- \( P_d \) = detected power
- \( P_{OL} \) = emitted power
- \( G \) = antenna gain
- \( \lambda \) = wave length
- \( \sigma \) = target radar cross section
- \( R \) = range
- \( L \) = losses (mismatch, plumbing and conversion)

The radar equation (2) provides a way to evaluate the detected power \( P_d \). The CCIR recommendation for this kind of services is to use the 10,525 GHz frequency emitter. This recommendations allows an I.F. band of 50 to 4000 Hz bandwith that corresponds with human motion (3 km/h) and a car speed of 200 km/h respectively. This very low I.F. implies a strong excess noise (1/f). The overall system conversion noise will therefore be almost double that contributed by thermal noise only (KTB) with a 5 KHz bandwith receiver. This reduction in sensitivity means a corresponding maximum range of only a \( (2)^{-1/4}R \) (where \( R \) is the range for a radar with a receiver without excess noise 1/f). That is not important for most applications.

Circuit Description

The microstrip configuration and its system equivalent circuit are presented in fig. 1 and fig. 2. The oscillator signal - \( f_{\text{PR}} = 10.525 \text{ GHz}, P = 100 \text{ mw} \) - goes through a directional coupler which provides the necessary power to pump the mixer before reaching the transmitter antenna. The signal scattered by a moving body goes directly through the directional coupler, then it is mixed with a sample of the emitted signal to obtain the doppler frequency \( f_d \).

Oscillator

The local oscillator is used both to generate the emitting signal, and to pump the...
The mixer diode in the receptor path. The active device used is a Gunn diode which gives enough output power (300 mw) to make amplification unnecessary.

The frequency of the oscillator is determined by the reactance of the slot antenna, which is, in fact, a resonant circuit tuned to the frequency of interest. There is no need for a stabilization device such as a dielectric resonator or a metallic cavity, because only short term stability is required. The circuit is then very simple and consists of a Gunn diode bonded to a microstrip line which is in turn, coupled to the slot antenna. The length of this section of microstrip line is calculated to provide the oscillation conditions, according to the measured Gunn diode device line [2]. The directional coupler inserted between the diode and the slot antenna acts basically as a transmission line section because the coupling is weak (15 dB).

The antennas

The antennas are slots cut in the ground plane of the microstrip circuit. (dotted line in fig. 2).

The transmitting antenna is connected to the oscillator through a directional coupler, while the receiving antenna is connected to the mixer through the second branch of the directional coupler.

The design of the slots is based on the works of Yoshikozo and Yoshimura [3] and additional experimental studies.

The distances from the open circuit in the transmission lines to the slots are λ/4, and the offsets of the slots relative to the lines allows for the adjustments of the antennas impedances.

Coupling between transmitting and receiving antenna is reduced to a minimum by placing the slots in the same axis.

The H plane and E plane patterns of the transmitting antenna are shown in fig. 3 and fig. 4 respectively. The half-power beamwidths are 90 deg and 80 deg, and the backward radiation is minimum.

The mixer

The mixer is formed by a single Schottky diode with no d.c. bias. The diode (HP 5082-2774) has a high cutoff frequency and gives a low conversion loss (Lc) with a minimum L.O. power.

Since as shown in the previous paragraph, the I.F. is a very low frequency signal it is not possible to make a filter good enough to obtain a conversion loss optimum. The selfbiased mixer current is closed by a 1 MΩ load of the I.F. amplifier output, and a high impedance (100Ω) λ/4 short circuited stub at the input.

The r.f. mixer load is a simple open stub (λ/4) at the output that insures the
Intruder Detector Radar

0 v. r.f. to the output diode, and without matching network in the input. The r.f. signal are added in a u-trip double directional coupler with 15 dB coupling factor and 9 dB directivity who provides 5 dBm of L.O. power to pump the diode.

Results
The measurements have been made with a 5 KHz bandwidth receiver 1 Mr input impedance and variable gain (60 dB maximum). We have obtained an oscilloscope response with an object of approximately 0.5 m² of radar cross section with a range approximately of 100 m. in front of the alarm, this is sufficient for most applications.

The system has an overall power consumption of about 5w, which is mainly due to the extremely low efficiency of the gunn diode.

Conclusions
A very low cost intruder radar detection alarm using only two semiconductors devices has been presented. The dimensions of the microwave circuit are only 6 x 3.5 cm² and the total volume including the heat radiator is 6 x 2 x 8 cm³ (smaller than a cigarettes box). This small size allows easy canceling, since only the slot antennas have to be exposed (fig. 5). Furthermore, the heat radiator could be avoided if considered necessary for canceling reasons.

References