A LOW-COST ACTIVE ANTENNA FOR PERSONAL COMMUNICATIONS

G. Avitabile, C. Salvador, G. Biffi Gentili

Dipartimento di Ingegneria Elettronica - University of Florence
Via S.Marta,3 50139- Firenze ITALY.

ABSTRACT

The paper introduces an active antenna module which performs both receiving and transmitting operations with an extremely reduced number of components. Receiving operations, in particular, are based on a quasi-regenerative approach, which guarantees an high sensitivity while maintaining a quite simple structure. Experimental results are reported describing a rugged 2.4 GHz ISM band prototype.

INTRODUCTION

The popularity of short-range microwave links and transponder based systems has been rapidly growing in the last few years, giving rise to a wide class of non-contact automatic identification and remote data collection applications. In these applications cost, size/weight and power consumption represent key requirements.

The use of planar antennas printed on low-cost substrates allows to satisfy these requirements, giving room to the designer ingenuity for which concerns the feeding structure and the front-end configuration.

An active antenna module, integrating the Rx/Tx sections, is introduced. The module makes use of a patch antenna as radiating element and of a single bipolar transistor to implement the various front-end functions. Transmitting operations are performed by switching on and off the active antenna power supply, while receiving operations are regulated in a quasi-regenerative mode by a low-frequency loop.

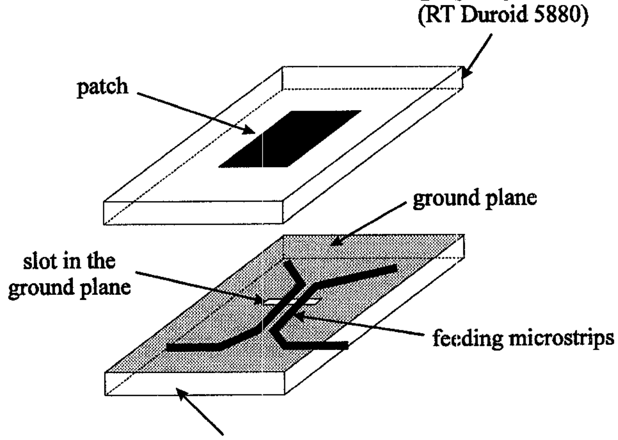

Fig.1. The radiating structure of the proposed active antenna

BASIC OPERATIONS

In its basic form, an active antenna is a standard microwave oscillator which uses the antenna as the frequency selective element. A rectangular patch, electromagnetically fed by two microstrip was chosen, in our case, as radiating element (Fig.1) [1]. The feeding slot is non-resonant. The structure results mostly suitable for self-oscillating operations, in that the two feeding ports intrinsically configure a low insertion loss resonator which can be used as control element of a phase-shift oscillator.

WE 3F

0-7803-3246-6/96/$5.00 © IEEE

1996 IEEE MTT-S Digest

The proposed active antenna schematic is depicted in Fig.3.

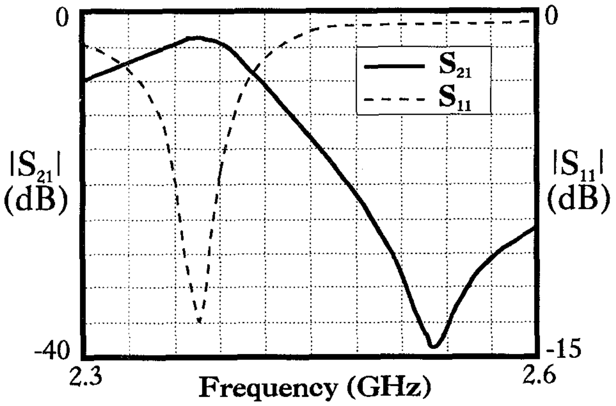

Fig.2. Measured S-parameters of a ISM band prototype of the two-port antenna

Fig.2 reports the measured insertion loss and reflection coefficient of a ISM Band prototype of the structure depicted in Fig.1 (antenna substrate: ε_r =2.2, tan δ = $18 \cdot 10^{-4}$, thickness = 0.8 mm ; microstrip substrate : ε_r=4.58 , tan δ =$164 \cdot 10^{-4}$, thickness = 0.8 mm).

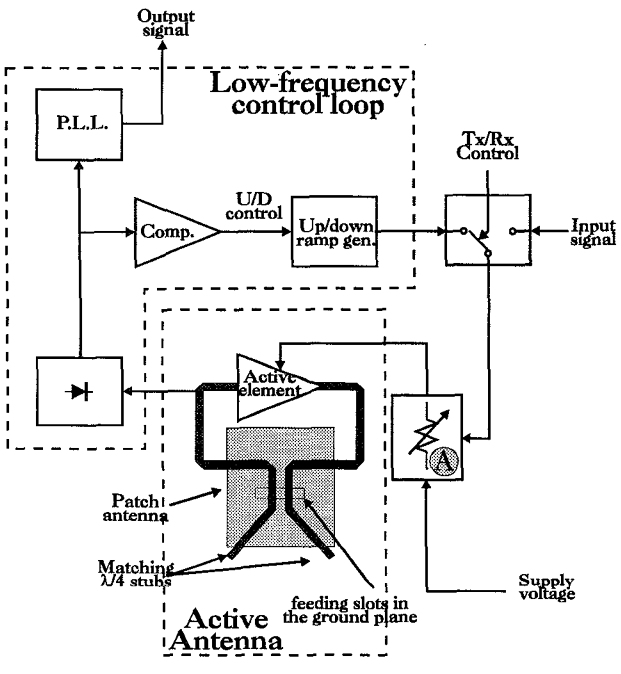

Fig.3. Block schematic of the proposed active antenna

Transmitting operations are simply obtained by controlling the oscillator supply (block A in Fig.3). The way in which this control is operated determines the obtained modulation: a continuous variation determines a frequency pushing in the oscillator, which results in a phase modulation [2], while a digital on/off control results in a amplitude modulation (OOK).

During Rx or stand-by the active antenna is controlled by a low-frequency loop which prevent stable oscillations to arise. In fact, the active antenna oscillation is checked by a detector, whose output is sent to a comparator which, in turn, controls an up/down ramp generator. The ramp generator is constituted by an up/down digital counter cascaded to a D/A converter. The DAC output supplies the active antenna. In this conditions, the loop gain of the phase-shift oscillator is forced to be close to unity, oscillating around this value with an amplitude determined by the LSB of the DAC.

Being the loop gain of the active antenna close to unity, a regenerative effect takes place, which affects, in particular, any in-band signal received by the antenna, whose power level is strongly increased by the virtually infinite oscillator gain. The consequent variation introduced by the loop in presence of an injected RF signal induces a frequency pushing in the active antenna, which can be detected by any commercial FM PLL.

It is worth to note that the proposed active antenna can detect both an incoming AM signal or a direct FSK signal. As a matter of fact, any in-band incoming signal stimulates an injection lock in the active antenna. The locking mechanism is stronger when the incoming signal frequency is close to the natural undumped active antenna frequency. As a result, taking into account the effect of the low frequency control loop, in presence of an OOK modulated incoming signal two frequency are detected: the former due to the active antenna itself (natural oscillation frequency), the latter induced by the incoming signal (injected frequency). On the other hand, if a FSK modulated signal is detected, two different frequencies are reported, both determined by the pushing of the incoming signal over natural active antenna frequency.

The detected frequencies for both types of modulation depend upon the 'distance' of the instanyaneous incoming frequency from the natural active antenna frequency.

EXPERIMENTS

In order to verify the active antenna operations, a 2.4 GHz ISM band prototype was constructed. The rectangular patch was designed using a RT-Duroid substrate (e_r=2.2, 0.8mm thickness). A 40 MHz antenna bandwidth @ VSWR=2 was experimentally found (patch dimensions: 39mm ^{x} 29 mm).
A general purpose bipolar transistor was used as active element in the phase-shift oscillator. Both the BJT and the low frequency circuit were mounted on a low-cost fiber glass reinforced plastic substrate (e_r=4.58, 0.8mm thickness).
A 8 bit DAC was used for the low-frequency loop control, being the bit number determined by the thermal noise of the antenna and of the detector, which strongly dominate the uncertainty in the control loop.
The overall active antenna size is 60 ^{x} 50 mm^2, with a thickness less then 4 mm.

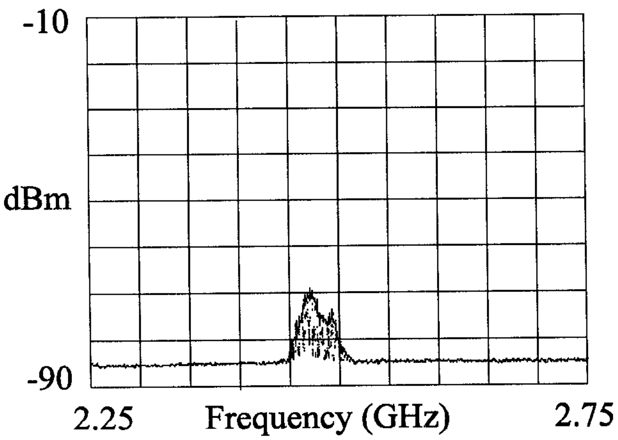

Fig.4. The spurious emission during stand-by, measured at a distance of 50 cm.

Fig.4 reports the power radiated by the antenna during stand-by, measured at a distance of 50cm.

The spurious emission is quite low (<-70 dB) and covers a frequency span mainly determined by the antenna bandwidth.
In order to ensure proper on-field operations, the thermal behaviour of the antenna has been tested. Stable operations were reported over a 0°÷+60° temperature range.

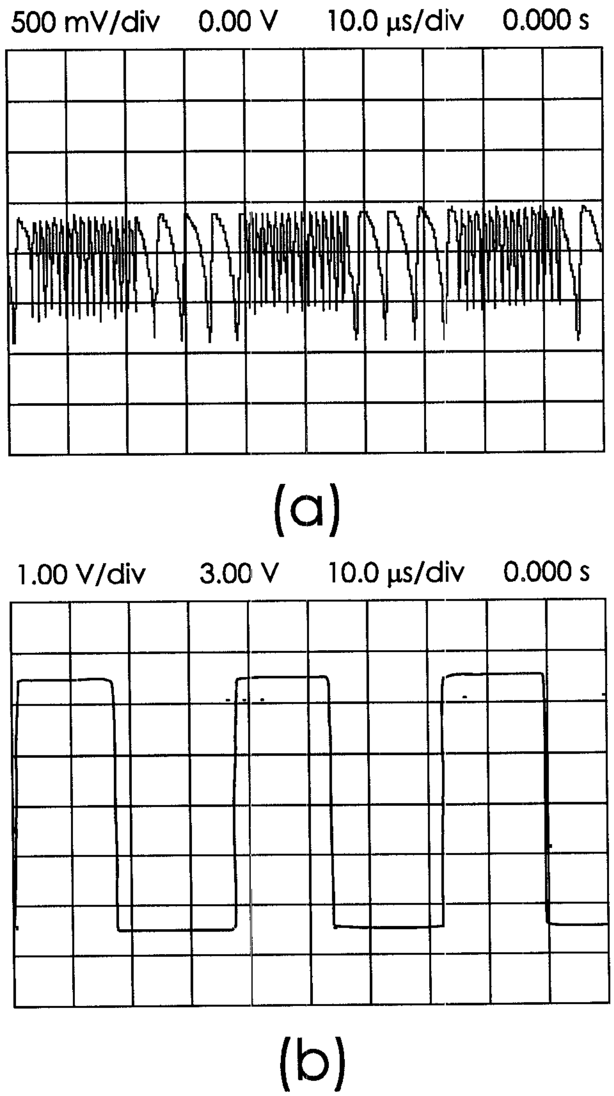

Fig.5. The received signal (OOK modulated) :
a) detector output; b) demodulated signal.

Fig.5.a shows the detected signal obtained in presence of an incoming FSK modulated signal (F=2450 Mhz, ΔF=4 Mhz, PRF=27 kHz). It can be easily seen that, as expected, the signal is FM modulated for effect of the frequency pushing. Fig.4.b shows the signal output by the PLL.

As expected, a similar result was reported using an incoming OOK modulated test signal.

Receiving sensitivity was evaluated by comparison with a similar passive patch antenna assumed as reference. A sensitivity in excess to -75 dB was reported.

Tx radiated power was evaluated with the same procedure, reporting a +9.5 dBm (EIRP) level.

CONCLUSIONS

The active antenna operations described assume a linear polarization. Actually, with a suitable arrangement of the patch antenna, a circular polarization is easily obtained, without any significant increase neither in terms of circuit complexity nor of overall size.

The proposed active antenna results extremely simple and frequency scaleable. The low-frequency section is suitable for a monolithic ASIC implementation, in order to obtain a further reduction of the active antenna size, which, in any case, is determined by the radiating structure area .

REFERENCES

[1] G. F. Avitabile, S. Maci, G. Biffi Gentili, L. Roselli, G. Manes, " Two ports active coupled microstrip antenna ", Elect. Letters, vol. 28, n.25, Dec. 1992.

[2] V.F. Fusco "Self detection performance of active microstrip antenna", Electronics Letters, 1992, vol.28, n.14, pp1362-1363.