A LOW-COST ACTIVE TRANSCEIVING ANTENNA

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ABSTRACT

This paper investigates the design of a compact injection locked active transceiving antenna. This transceiver is well suited for low power and low cost wireless applications. A center-slotted square patch antenna, two bipolar transistors and a dual gate FET are used. The antenna operates at 1.4 GHz with 4.39 dB gain and a maximum usable sensitivity of -97 dBm.

INTRODUCTION

With the release of frequency spectrum for Low Power Device (LPD) in Europe and ISM band in USA, a need for low cost and compact transceiver arises. Applications are plentiful, such as location and despair system for senior citizen, wireless modem, etc. In the design of these systems, since governmental requirement on the specifications are less stringent, the engineer is at liberty to find alternative designs that employ cheaper and smaller number of components. Moreover, the use of Frequency Domain Duplex with different transmit and receive time slot as demonstrated in GSM system allow for less expensive designs (T/FDD). In this paper, a transceiver utilizing this T/FDD is presented (see Figure 1). It is compact, simple and convenient for both wall-mounted base station and hand-held or body-mounted portable station.

ANTENNA GEOMETRY/CIRCUIT DESIGN

Figure 2 shows the basic schematic of the antenna. The center-slotted patch antenna

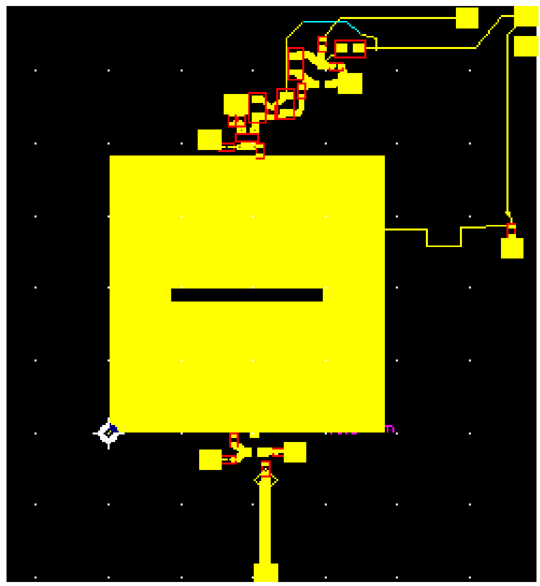


Figure 1

has the property of wide bandwidth and good radiation efficiency. Different shapes of the slot provides different bandwidth that can be adjusted by the engineer according to actual requirements. Here we show an example using the simplest center-slot configuration.

The circuit is divided into two parts: (i) active antenna injection locked oscillator [1,3], (ii) active mixer. During the transmit time slot, the injection signal that contains modulated information is injected into the BJT oscillator. The antenna then radiates the locked signal energy out. During the receive time slot, the same injection signal, now wit hout the modulated information, is again injected to the BJT oscillator. Only that this time the locked signal acts as the local oscillator for the mixing of the incoming signal. The local oscillator and the incoming signal are mixed at the FET which produces the IF signal entering the buffer BJT. After that the signal can be demodulated using any common demodulation chip.

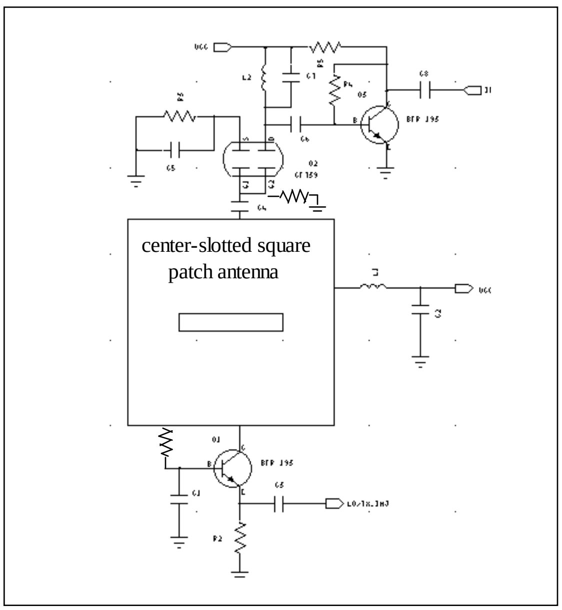


Figure 2

At the injection locked oscillator circuit, the antenna acts as a resonating port, the equivalent circuit can be found from [2]. A Siemens BJT BRF193 in common base configuration is used as the active device. The patch is fed into the collector of the BJT. The dimensions of the patch antenna is 1.384 cm squared. The feeding point is at the center of one radiating edge of the antenna. The f_T unity gain of the transistor is up to 8GHz. To avoid causing any loading effect to the oscillation, the biasing point is placed at the non-radiating edge of the antenna. Radiation from the patch is linearly polarized. The oscillator drains about 17 mA current at 5V and the radiated power is -22 dBm measured at 0.4 m distance using an HP 11966E receiving horn. At the active mixing port, a dual gate FET is placed at the center of the edge opposite to the injection locked oscillator where maximum voltage can be delivered to the gates of the FET. The DGFET is a Siemens product with maximum gate capacitance below 0.8 pF. The drain of the FET is connected to an IF tank circuit and a buffer transistor.

DESIGN RULES

To design the active antenna such that the oscillation frequency and polarization are within the desired specification. It is necessary to tune and control the following parameters:

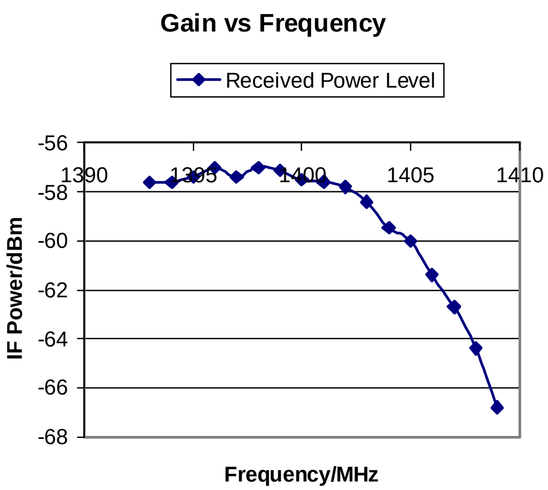
(i) The position of the active oscillating BJT at the antenna. One should note that the BJT is a negative resistance device here. The exact input impedance looking into the antenna must be matched to this negative resistance.

(ii) The position and the attachment point of the bias line. In general it should be connected to the antenna along the non-radiating edge.

(iii) The attachment point of the Dual Gate FET. One should note that the FET is a tranconductance device with output sink current controlled by the voltage at the gates. Therefore the gate should be attached to the maximum voltage point of the antenna.

MEASUREMENT: RECEIVING GAIN VS FREQUENCY

The active transceiver is placed 1 meter away from the transmitting horn fed by a source of –30 dBm. The IF frequency is chosen to be 6 MHz and both superdyne and infradyne mixing are tested (high-side and lowside mixing). The injection power is 0 dBm and received power is measured over the locking bandwidth. Figure 3 is the measured result. As the frequency is increased, the receiving gain gradually decreases. The receiving gain is not symmetric within the locking range.



RECEIVING GAIN VS DC SUPPLY

Using the same configuration as the last section, the receiving gain is measured while varying the DC supply. The device can operate down to 2 Volt with the IF power output of –75 dBm. As one increases the supply voltage to 6 Volt the IF power reaches -50 dBm.

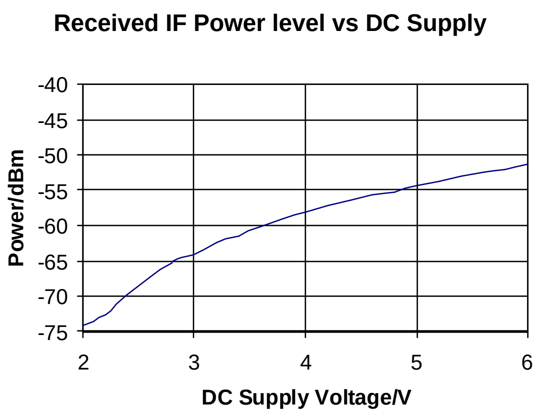


Figure 4

SENSITIVITY

The sensitivity of the device is tested by using it to receive a transmitter placed 1 meter away. The IF output is fed into a demodulator with known sensitivity.

The maximum usable sensitivity is defined as the power level radiated from the transmitting horn such that the SINAD of the recovered audio is equal to 20 dB. For co-polarization, the sensitivity is –97 dBm. For cross polarization, the sensitivity is –87 dBm.

RADIATED POWER VS FREQUENCY

The resonating frequency of the antenna is 1.4 GHz. The locking bandwidth is 16 MHz when the injection signal is 0 dBm. The radiated power measured using the HP11966E horn at 40 cm away versus frequency is shown in figure 5. The peak happens at around 1.4 GHz, which is the natural resonance frequency of the patch antenna.

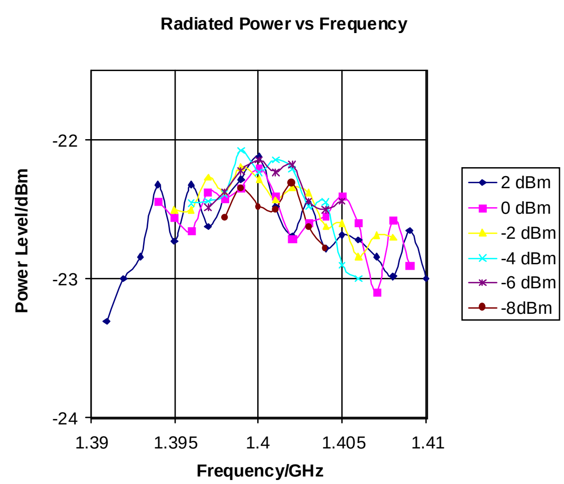


Figure 5

LOCKING BANDWIDTH VS INJECTION POWER

The locking range versus injection power is shown in Figure 6. As expected, the locking bandwidth increases from 8 MHz to 37

MHz when we increase the injection power from -9 dBm to 9 dBm. Of course, in most of the applications this system is designed for, the actual bandwidth requirement will remain in the low end of this graph.

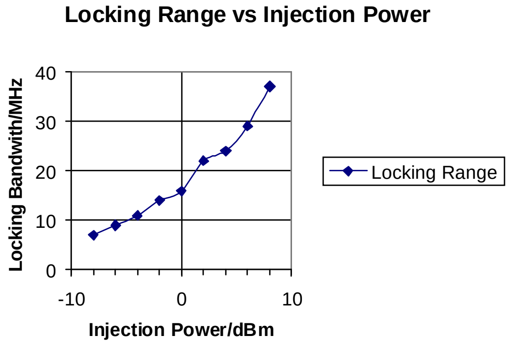


Figure 6

RADIATION PATTERN

The radiation pattern of this antenna is typical of patch antenna with slightly sharper main beam. The 3 dB beamwidth is 120^0 in the E-plane and 125^0 in the H-plane. The gain is approximately 4.39 dB. The front-to-back ratio is around 10 to 14 dB. This is good for portable applications where illumination of the user may not be desirable.

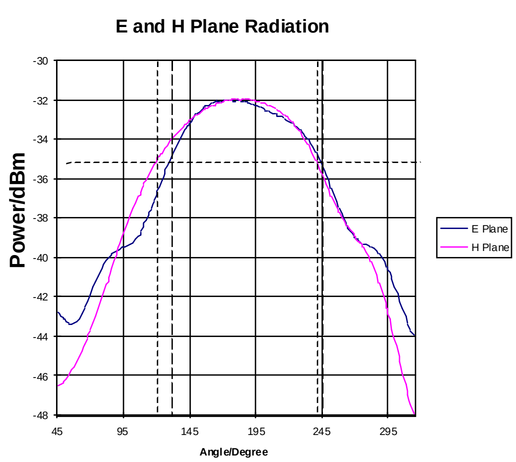


Figure 7

DISCUSSION

This transceiver incorporates the latest advances in patch antenna technology and injection locked circuit designs. Many variations can be made in terms of polarization diversity, injection locking parameters, etc.

The power radiated by this active antenna is strong enough for low power applications. Transmit power cannot be too large for this circuit anyway because of the direct connection between transmit and receive circuitries.

In this transceiver there is no need to use expensive high quality band-pass filter to isolate the transmitting and receiving frequencies, since the transmitting signal serve as the LO. With this simplification, the circuit architecture is less expensive to fabricate. As mentioned before, this kind of transceiver can be applied to system employing TDD with different transmit and receive frequencies.

ACKNOWLEDGEMENT

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