BROADBAND, LOW-NOISE ACTIVE RECEIVING MICROSTRIP ANTENNA

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ABSTRACT

An active receiving microstrip antenna operating around 10 GHz with a GaAs MESFET as active part of the antenna is presented. With the design proposed here, low-noise active receiving antennas with considerably improved bandwidth can be realized. Simulated and measured results of noise figure and power gain along with the corresponding bandwidth are given in addition to customary antenna parameters. Possibilities for noise figure measurement with this non-insertable device have been investigated and an alternative to known procedures is presented.

INTRODUCTION

Although microstrip antennas have found widespread applications both as transmitting or receiving elements, only a few articles have been published dealing with active receiving microstrip antennas /1/-/4/, all operating at frequencies well below 10 GHz. With the antenna described in this contribution, active receiving antenna design can be extended to higher frequencies with improved bandwidth and noise performance.

One of the structures that is well suited to the integration of a transistor is the aperture coupled microstrip antenna (e.g. /5/) according to Fig. 1. It offers a number of parameters for the optimization, and due to the shielding ground plane, the radiation pattern is not affected by the active circuit on the backside of the structure. By properly choosing all the parameters, broadband, low noise receiving antenna elements can be designed, operating with a minimum of matching circuits between passive antenna and transistor and therefore reducing losses and overall noise figure.

THEORETICAL DESCRIPTION OF THE PASSIVE ANTENNA ELEMENT

For the calculation of the radiation pattern and the input impedance of the passive antenna, a more general equivalent structure with lateral shieldings according to Fig.2 was investigated using the spectral domain method /8/. The complete structure is separated in two parts, coupled via magnetic currents in the slot. With this general formulation of the problem, antennas as well as corresponding transitions from microstrip line to rectangular waveguide, proposed by the authors in /9/, can be treated. For open structures, however, the effect of the lateral shieldings concerning surface waves must be eliminated by introducing a small amount of dielectric losses (ε_{ri}'') in the upper region (e.g. /10/), thereby avoiding the need for calculating the poles in the Green's functions. The input impedance of the structure, defined with respect to a reference plane on the microstrip line, can be extracted by assuming a current source (J_s) at an appropriate distance from the slot and evaluation of the standing wave pattern on the feedline.

DESIGN OF THE ACTIVE ANTENNA

The active antenna was optimized primarily for low noise performance, keeping the bandwidth as high as possible.

Usually, a transistors is matched for minimum noise via matching networks, but this generally introduces additional losses and bandwidth limitations. In the design presented here a matching was simply achieved by properly choosing all the involved impedances. The design starts with the determination of the passive antenna impedance required for minimum noise figure, deduced from the transistors S- and noise parameters at the center frequency. An appropriate antenna synthesis is performed, taking advantage of the free parameters inherent to the structure. Particularly, the characteristic impedance of the feeding line was chosen equal to the real part of the impedance required for minimum noise figure. After a frequency-dependent analysis of the antenna structure, bandwidth can be optimized by properly selecting the line length between antenna feed point and transistor using a common CAD-program. The procedure is facilitated by a proper theoretical computation of the antenna impedance, as the feeding line impedance typically differs from the 50 Ω measurement system. In this way, a considerable improvement of bandwidth is achieved compared to a passive antenna with 50 Ω microstrip feed line (16 % compared to 6%).

NOISE MEASUREMENT

Some possibilities were investigated to measure the noise performance of the active antenna, represented by the noise figure of the embedded transistor. In /3/, a method based on the principle of the minimum detectable signal with its inherent drawbacks compared to hot/cold load measurements is proposed, and in a set-up according to /1/, the problem of amplifying and transmitting weak noise signals arises. Another possibility therefore was applied here for simplicity, using a modified hot/cold load procedure. In a set-up similar to those described in /1/, /6/, a passive, impedance matched reference antenna was mounted inside an anechoic chamber and illuminated by a transmitted sinusoidal signal. By measurement of the received power with a calibrated noise figure meter, an equivalent "ENR" (Excess Noise Ratio) can be defined, and an assignment between transmitted signal power and this equivalent, artificially generated ENR can be made. Subsequently, a straightforward hot/cold load measurement can be performed with the active device, using signal off/on states instead of hot/cold loads.

For comparison, the methods described in /1/, /3/ were applied at 10 GHz, too, and an agreement within 0.4 dB was achieved. None of these methods accounts for losses due to the passive antenna. This problem could be solved applying a much more complicated procedure, proposed in /7/, where the antenna is operated in a hot/cold environment with loads of known temperatures, e.g. liquid nitrogen at the boiling point (77.36 K). In this way, (passive) antenna losses as well as the overall noise temperature of an active receiving antenna could be measured directly, but this was not done yet.

RESULTS

In a first step, the radiation pattern of the active antenna at 10 GHz was compared to that of the impedance-matched passive element, Fig. 3. The patterns are nearly equal, except for the active antenna showing an extra power gain of about 10dB. Fig. 4 shows the frequency-dependent power gain (defined as in /6/) of the active antenna, found by comparison with a standard gain horn. A bandwidth of about 1.6 GHz (16 %) was achieved. Fig. 4 also shows the measured noise figure, compared to the simulated values deduced from the data-sheet of the transistor and the measured passive antenna impedance. Furthermore, the minimum noise figure of the transistor is plotted as a reference. A noise figure of less than 3dB was obtained over approximately the same frequency band as the power gain bandwidth.

CONCLUSION

A simple active receiving microstrip antenna element has been designed and fabricated. Compared to the corresponding passive antenna, a considerable increase in bandwidth and power-gain has been achieved, and the transistor is operated near its noise minimum over the whole region of interest. Due to the passive antenna structure chosen here, the radiation pattern is not affected by the active circuit, and backside radiation is small. Further improvement of the performance can be expected by improved passive antenna designs and, of course, implementing a superior transistor.

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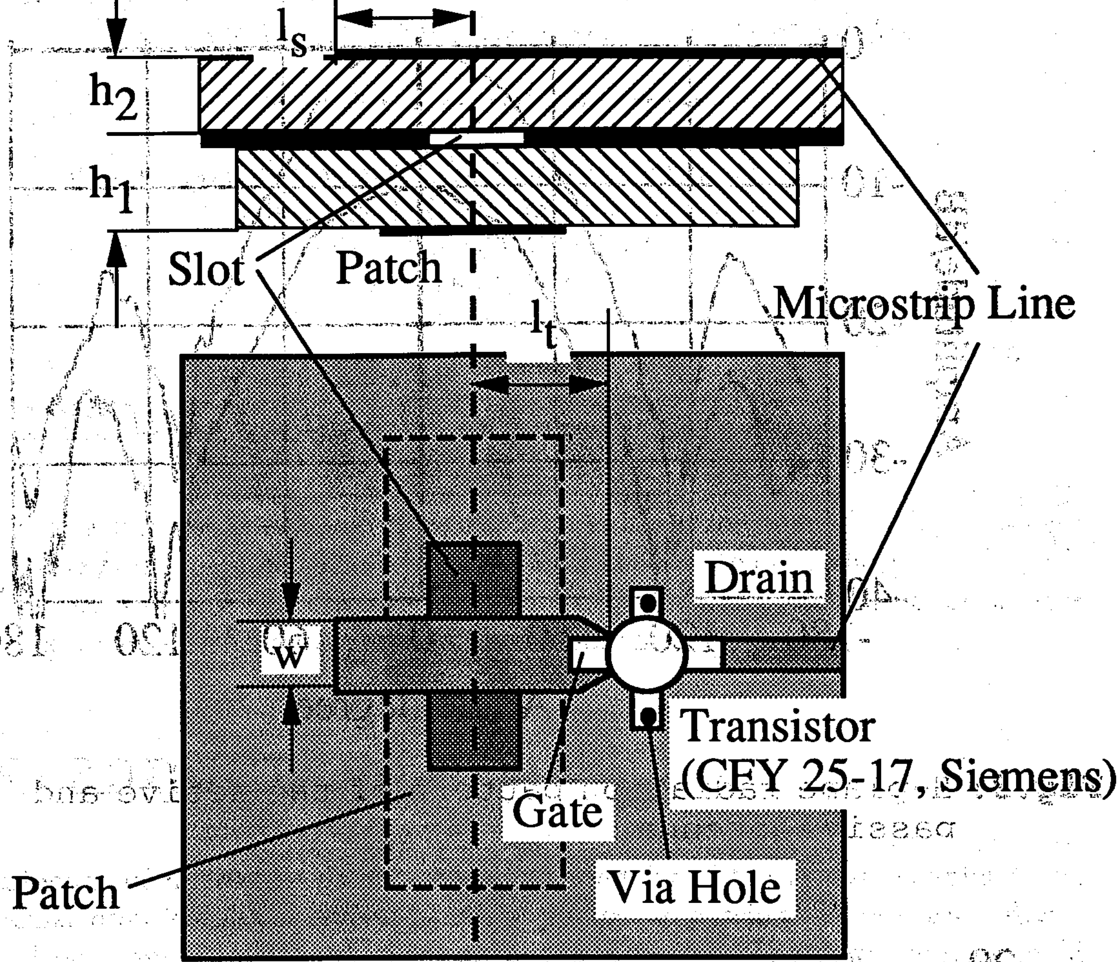

Fig. 1: Basic configuration of the active antenna (Patch 8x12 mm, slot 0.5x4.6 mm, ε_{r1}=2.33, ε_{r2}=10.8 h_1=1.57mm, h_2=0.64mm, l_s=1.1mm, w=2.577mm (20Ω), l_t=2.0mm)

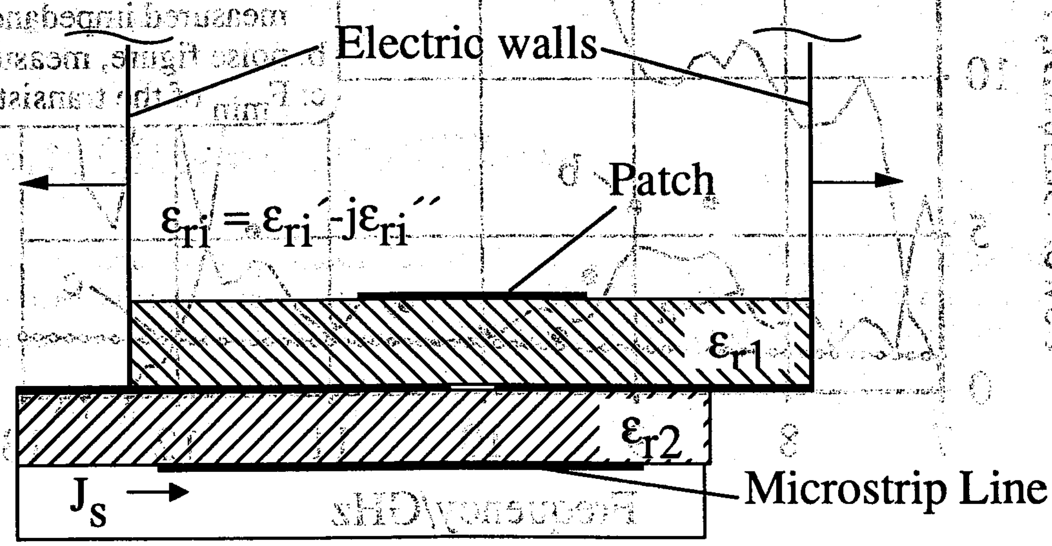

Fig. 2: Equivalent structure for theoretical analysis of the passive antenna

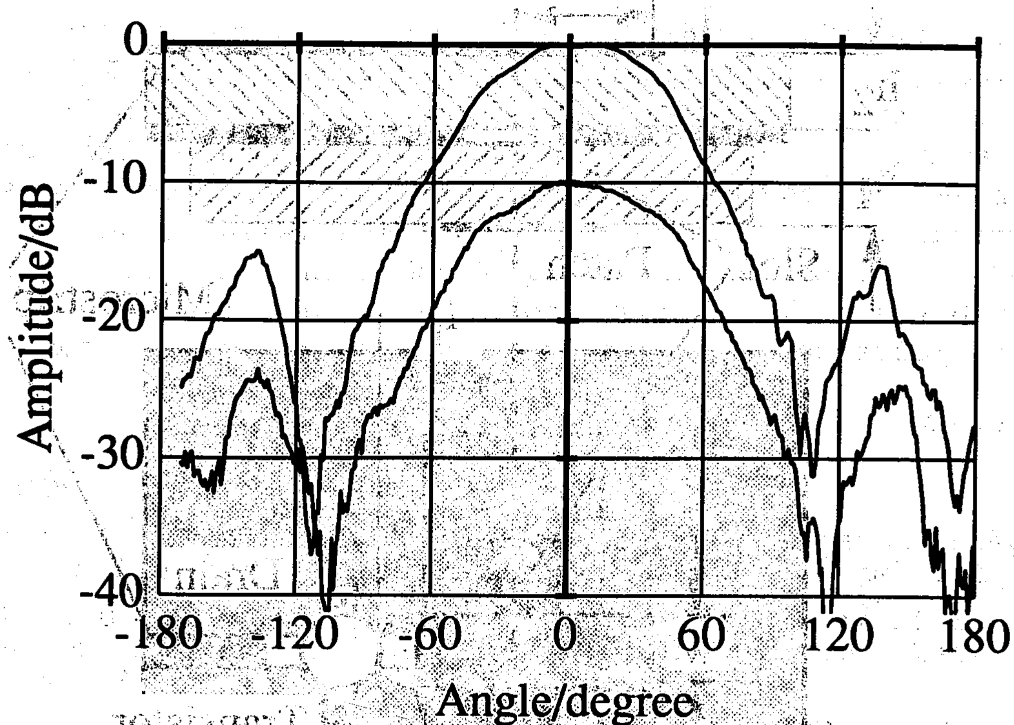

Fig.3: H-plane radiation pattern of the active and passive antenna

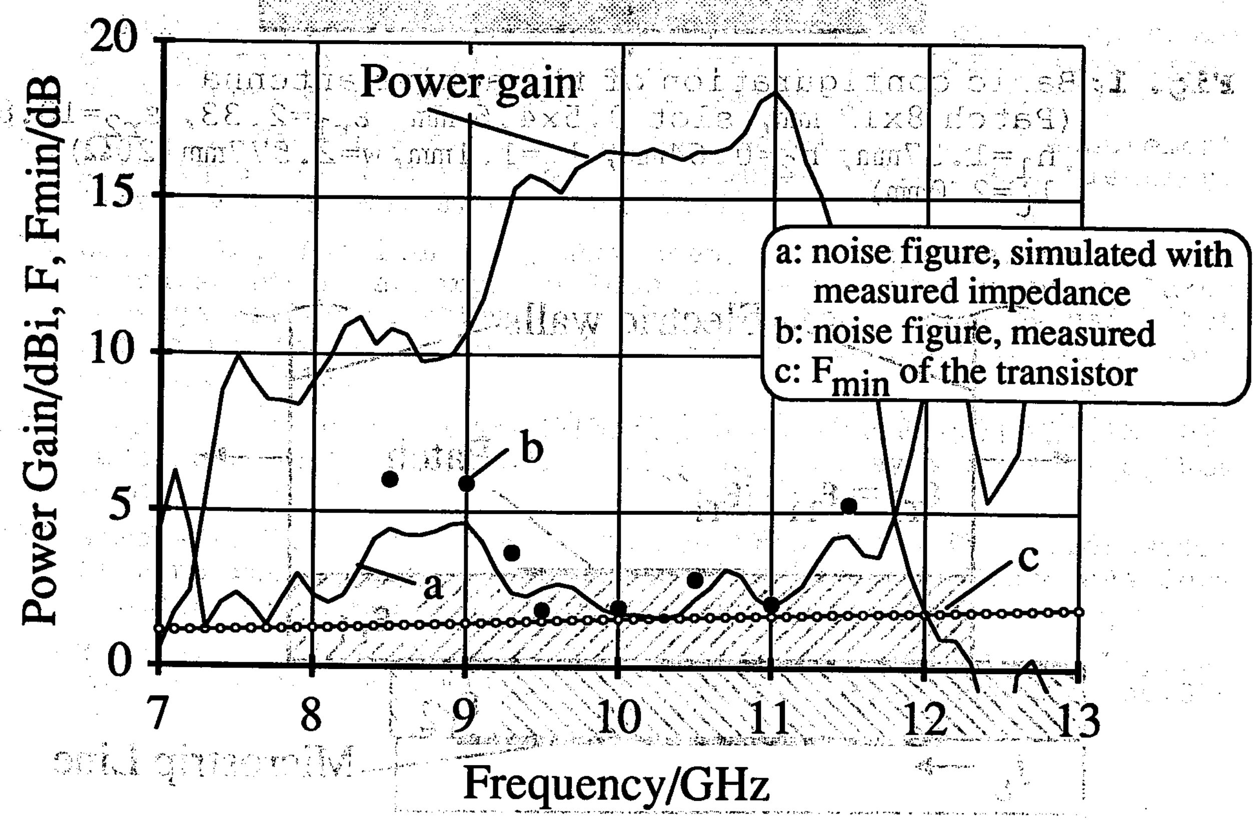

Fig. 4: Power gain and noise figure of the active antenna