ACTIVE LOW NOISE TRANSITION FROM RECTANGULAR WAVEGUIDE TO MICROSTRIP LINE

Wilfried Grabherr and Wolfgang Menzel

University of Ulm, Microwave Techniques
D-89069 Ulm, Germany

ABSTRACT

An active transition from rectangular waveguide to microstrip line, operating in X-band with a GaAs MESFET as integral part of the transition is presented. The design allows for low noise amplification of the signal with improved bandwidth compared to the corresponding passive transition. Measured results of noise figure and power gain are given.

INTRODUCTION

A new kind of transitions from microstrip line to rectangular waveguide, based on the concept of slot-fed microstrip antennas, was previously proposed by the authors and has proven to work well in the microwave and mm-wave region /1/,/2/. The advantage of these transitions compared to other concepts (e.g. /3/-/5/) is based on the fact, that waveguide structures are necessary only on the backside of the substrate, allowing planar circuits on the top side to be extended all around the transition and thus making it compatible with MICs or MMICs, respectively.

In this contribution, the possibility of integrating a low noise transistor amplifier according to Fig.1 with a GaAs FET positioned very close to the coupling slot is demonstrated. Compared to simply cascading separately matched transitions and amplifiers, the principle of integrating the transistor as a non-separable part of the component gives additional freedom in the design, resulting in superior performance with regard to noise figure and bandwidth.

THEORETICAL DESCRIPTION OF THE PASSIVE TRANSITION

The calculation of the passive part of the transition is based on a modified spectral domain method /6/. The basic spectral domain method can not be applied here directly due to different lateral structures above and below the ground plane, see Fig. 2. As has been outlined in /7/, introducing magnetic surface currents M in the slot region allows for replacing the slot by a perfectly conducting plane. Thus, two separate structures I and II can be created, each of them suitable for conventional full wave spectral domain analysis. Both open and shielded structures as well as combinations of them can be analyzed using this method, thus a great flexibility is achieved. The S-parameters of the structure finally can be extracted by introduction of an impressed current J_s on the feedline and evaluation of the corresponding field and current distributions; e.g. the standing wave pattern on the feedline yields the reflection coefficient at the microstrip port.

DESIGN OF THE ACTIVE TRANSITION

The active transition was optimized primarily for low noise performance, trying to keep the gain and bandwidth as high as possible. In this concept, the need for an extra matching network, which generally introduces additional losses and bandwidth limitations, was avoided by a proper design of the passive part of the transition.

The design starts with the determination of the impedance required for minimum noise figure according to the transistor's S- and noise parameters, which are measured or taken from the data sheet. An appropriate synthesis of the passive transition is performed at the center frequency, taking advantage of a great number of free (geometrical) parameters inherent to the structure. Particularly, the characteristic impedance of the microstrip feeding line, determined by the line width, is chosen equal to the real part of the impedance required for minimum noise figure, so it typically is different from 50 Ω. After a frequency dependent analysis of the passive structure, bandwidth of the overall structure can be optimized by properly adjusting the line length between coupling slot and transistor, using a common CAD-program.

RESULTS

According to the transistor's noise parameters and following the design procedure outlined above, a characteristic impedance of 20 Ω was found to be appropriate for the feedline. The simulated return loss of the basic passive transition is given in Fig. 3. Since the impedance of 20 Ω differs from the 50 Ω measurement system, a rather time consuming measurement procedure using a vector network analyzer with TRL calibration generally must be used for experimental verification. This however was considered to be unnecessary here, due to the fact that the simulated results have proved to be very reliable (e.g. /1/, /2/). Measured results of noise figure and gain of an active transition realized at X-band are given in Fig. 4 and 5. The waveguide port is denoted as port 1, the microstrip port as port 2. A gain of about 8 dB is achieved over a 2 GHz bandwidth (9.8 - 11.8GHz) with a noise figure of less than 2.3dB. To demonstrate the principle, a rather simple MESFET was chosen, the minimum noise figure provided by the transistor is plotted as a reference. Considerable improvement with regard to the absolut values however can be expected by implementing superior transistors, for example HEMTs.

CONCLUSION

An active low noise transition from rectangular waveguide to microstrip line, based on the principle of slot coupled microstrip antennas, has been presented. The possibility of integrating a transistor as a non-separable part of the transition is shown and the advantages of this set-up are outlined. Measured results of gain and noise figure are given. Compared to the corresponding passive transition, an increase in bandwidth in conjunction with low noise amplification of the signal has been achieved. One possible extension to the concept of this active transition may be to simply add a horn antenna to the waveguide, thus leading to an active waveguide receiving antenna with low noise properties, as it was developped in a similar way for corresponding planar antennas in /8/.

REFERENCES

/1/ Grabherr, W.; Menzel, W.: "A new transition from microstrip line to rectangular waveguide". 22nd European Microwave Conference, 1992, Helsinki, Finland, pp. 1170-1175

/2/ Grabherr, W.; Huder, B.; Menzel, W.: "Microstrip to Waveguide Transition Compatible With MM-Wave Integrated Circuits". IEEE Trans. Microwave Theory Tech., vol 42, pp.1842-1843, Sep. 1994

/3/ Ho, T.Q.; Shih, Y.: "Spectral-domain analysis of E-plane waveguide to microstrip transitions", IEEE Trans. Microwave Theory Tech., vol. 37, pp. 388-392, Feb. 1989

/4/ Lavedan, L.J.: "Design of waveguide-to-microstrip transitions specially suited to millimetre-wave applications", Electron. Lett., vol. 13, Sept. 1977

/5/ Menzel, W.; Klaassen, A.: "On the transition from ridged waveguide to microstrip", Proc. 19th European Microwave Conf., 1989, pp.1265-1269

/6/ Itoh, T.: "Numerical Techniques for Microwave and Millimeter-Wave Passive Structures", New York: John Wiley & Sons, Inc, 1989

/7/ Chan, C.H.; Ng, K.T.; Kouki, A.B.:"A Mixed Spectral-Domain Approach for Dispersion Analysis of Suspended planar Transmission Lines with Pedestals", IEEE Trans. Microwave Theory Techn., vol. MTT-37, No. 11, Nov. 1989, pp. 1716-1723

/8/ Grabherr, W.; Menzel, W.: "Broadband, low-noise active receiving microstrip antenna", Proc. 24th European Microwave Conference, 1994, Cannes, France, pp. 1785-1790

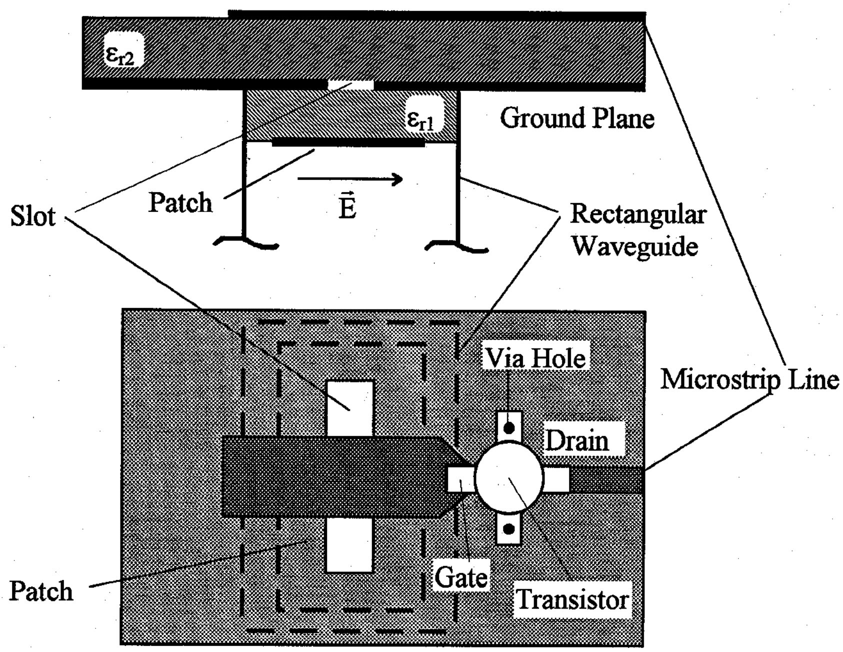

Fig. 1: Basic configuration of the active transition (bias network is not shown)

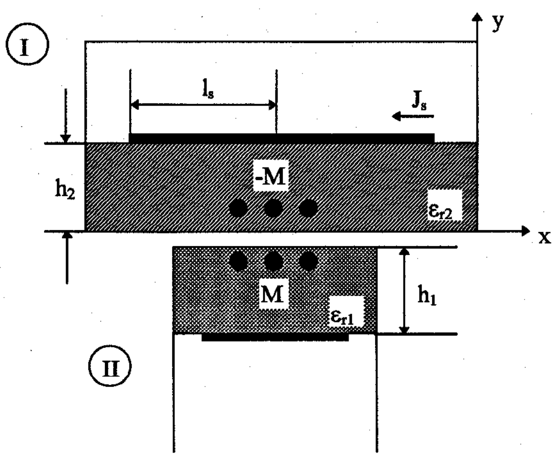

Fig. 2: Set-up for theoretical calculation

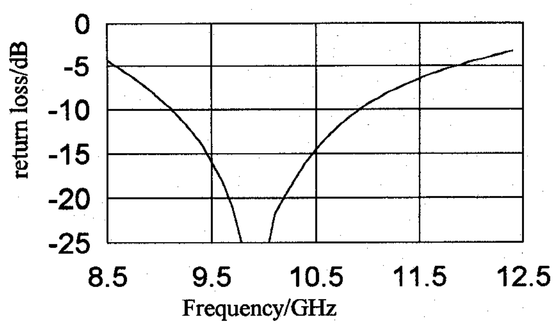

Fig. 3: Calculated return loss of the passive transition (values normalized to 20 Ω)
ε_{r1}=2.33; ε_{r2}=10.8; h_1=1.57mm; h_2=0.64mm;
patch: 7.4 x 8.5mm; slot: 1.4 x 4.9mm;
waveguide: 10.16 x 22.8 mm (X-Band)
microstrip: w=2.58mm; l_s=0.9mm

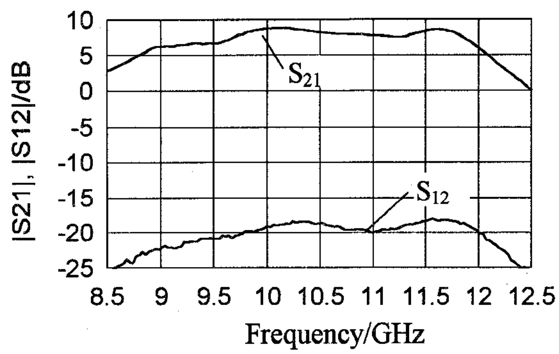

Fig. 4: Measured S_{21} and S_{12} of the active transition (port 1: waveguide; port2: microstrip)

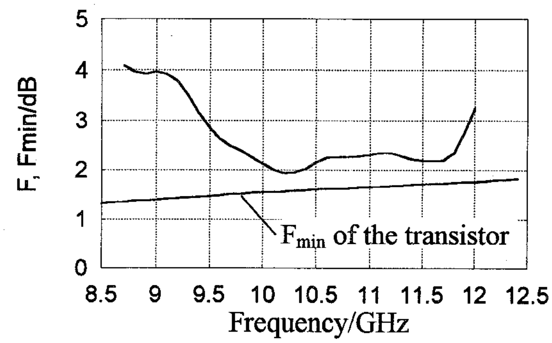

Fig. 5: Measured noise figure of the transition