

# Ultrawideband Power Detector GaAs MMIC's

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**Abstract** – The results of design and manufacturing of absorbed power detectors MMIC's and directional power detector MMIC with frequency range up to 40 GHz based on zero-bias diodes are presented in this paper. Measured S-parameters show input return loss less than -18 dB. Absorbed power detector have 80 dB dynamic range. Directional power detector have low insertion loss (less than 2 dB), high voltage sensitivity and directivity more than 12 dB.

**Index Terms** – zero-bias diode, gallium arsenide, monolithic microwave integrated circuit, RF power detector.

## I. INTRODUCTION

**D**ETECTOR is one of the basic elements in the modern RF and microwave measurement equipment, which function is to identify and control the level of microwave power applied to the input. Detector is a part of the microwave power devices, sensors and VSWR circuit analyzers. Detector must meet special requirements: wide dynamic and frequency ranges, low noise level, necessary video bandwidth, good impedance matching and high voltage sensitivity.

Detector circuits are often manufactured as hybrid circuits or micro assemblies [1]. However, using of monolithic microwave integrated circuits (MMIC) instead of micro assemblies allows improving performance of the equipment, simplifying the process of assembling and setup, and as a result increasing product quality.

## II. PROBLEM DEFINITION

Currently there is a production of GaAs MMIC's for different purposes [2] in “Micran” company (Tomsk, Russia). Some types of “Micran”'s products including microwave measurement equipment require specified MMIC components, including absorbed power detectors and directional power detectors based on zero-bias diodes in the frequency range up to 40 GHz, for improving the performance and to design new devices.

## III. THEORY

Power detectors are designed on the basis of gallium arsenide zero-bias diode technology [3]. Diodes made by this technology, have both high tangential sensitivity and wide dynamic range compared to the dynamic range of the unbiased Schottky diode, small specific capacitance, allowing to realize ultra wideband (UWB) circuit solutions. An important feature of such diodes is the ability to control barrier height in a wide range (from 0 V) during the stage of the semiconductor structure design. Main advantages of zero-bias diode in comparison to a Schottky diode

are a lower sensitivity to surface quality, smaller low-frequency noise level, higher temperature stability and resistance to electrostatic discharge. Typical parameters of the zero-bias beamlead diode produced by “Micran” are shown in table 1 [4]. Equivalent circuit of the diode is shown on Fig. 1.

TABLE I  
PARAMETERS OF THE ZERO-BIAS BEAMLEAD DIODE  
EQUIVALENT CIRCUIT

Parameter	Value
$R_s$ , Ohm	30
$C_p$ , fF	11
$C_j (U=0V)$ , fF	31
$r_j (U=0V)$ , kOhm	0,9
$L_{BL}$ , nH	0,3

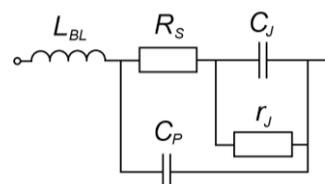


Fig. 1. Zero-bias beamlead diode equivalent circuit

## IV. EXPERIMENTAL RESULTS

The microscopic images of absorbed power detector MMIC's MD901 and MD903 are shown on Fig. 2 and 3 (images are partially hidden).

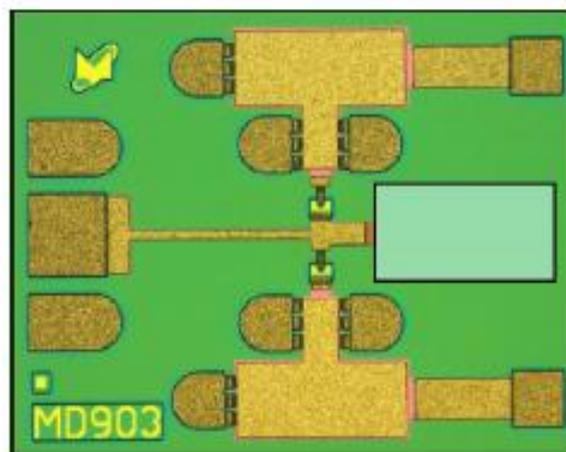


Fig. 2. MD903 absorbed power detector MMIC

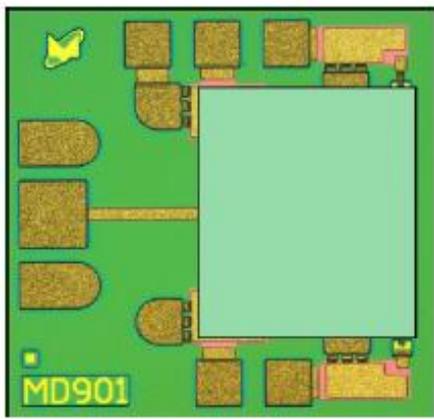


Fig. 3. MD901 absorbed power detector MMIC

MD903 MMIC is an amplitude detector based on two anti-parallel diodes to detect positive and negative half-waves of the microwave input signal. The dependence of the output voltage from the input power is shown on Fig. 4. At low levels of input power detector has a square law detection that allows the use of detectors for measuring modulated signals. Output voltage in this region is proportional to the input RF power. This dependence becomes quasi-linear, and then linear after exceeding power of -20 dBm. In two latter modes detector is useful for continuous wave power detection. MD901 MMIC contains two paths of detection: the low power path and the high power path. This allows extending the square-law region of transfer characteristic of whole MMIC. The experimentally measured transfer characteristics of MD901 detector for different frequencies of the input signal are shown on Fig. 5.

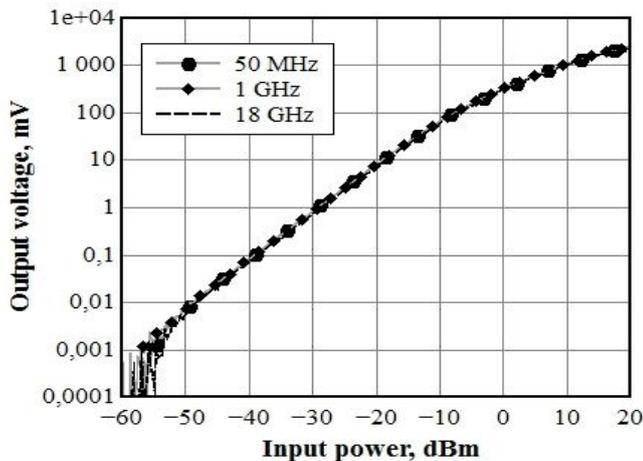


Fig. 4. MD903 transfer characteristics

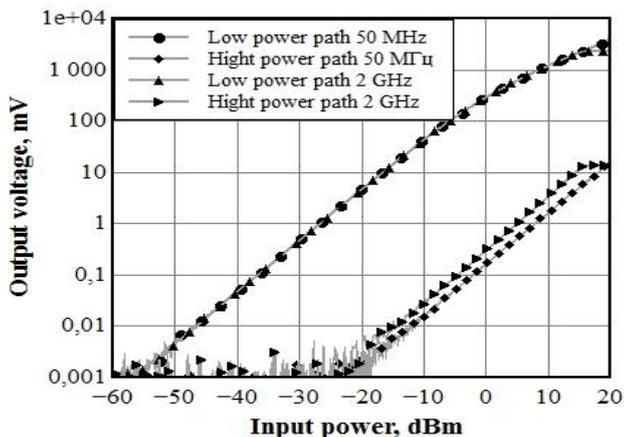


Fig. 5. MD901 transfer characteristic

Absorbed power detectors can be used both for measuring the average or the RMS power, and for impulse measurements. The use of additional external capacitors will allow setting the desired value of video bandwidth. The measured MMIC transfer characteristic without external capacitors corresponded to the regime of pulse signal measurement is shown on Fig. 4 and 5. Increasing the output capacitance reduces video bandwidth, but leads to an extension of transfer characteristic due to the reduced minimum of detection power. Return loss  $|S_{11}|$  of MD901 and MD903 are shown on Fig. 6. The maximum allowable input power of MMIC is at least 24 dBm with prolonged exposure and at least 30 dBm for pulse mode.

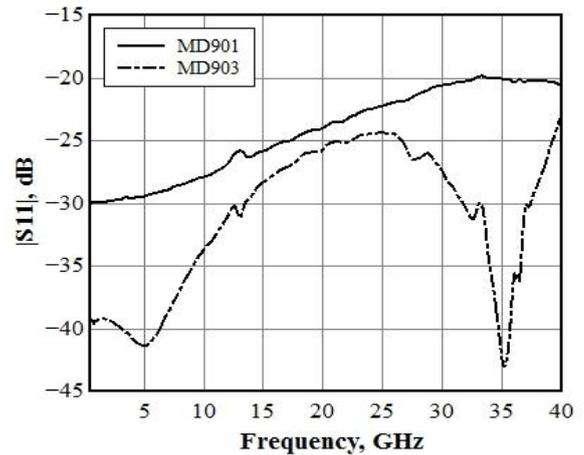


Fig. 6. MD901 and MD903 return loss

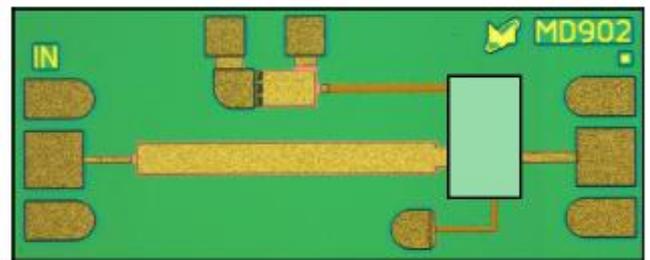


Fig. 7. MD902 directional power detector MMIC

Fig.7 shows the microscopic image of the MD 902 directional power detector MMIC. It comprises a resistive bridge with single zero-bias diode. This solution yields good frequency response and square law transfer characteristic over a broad band. Return loss  $|S_{11}|$  of MD902 MMIC is shown on Fig.8.

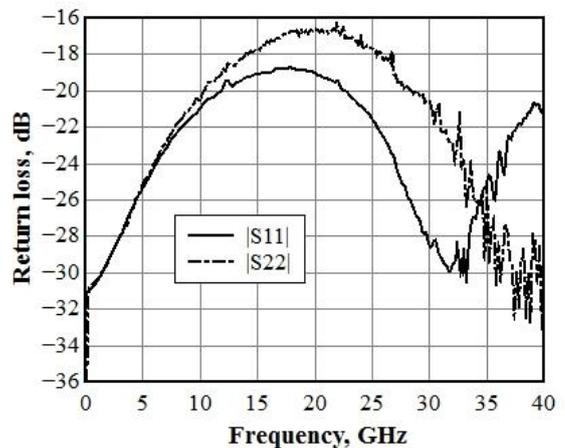


Fig. 8. MD902 return loss

The maximum allowable input power is more than 30 dBm with prolonged exposure in case of good output VSWR. For poor output VSWR maximum power decreases to 20 dBm. Fig. 9 shows measured insertion loss of MD902 MMIC.

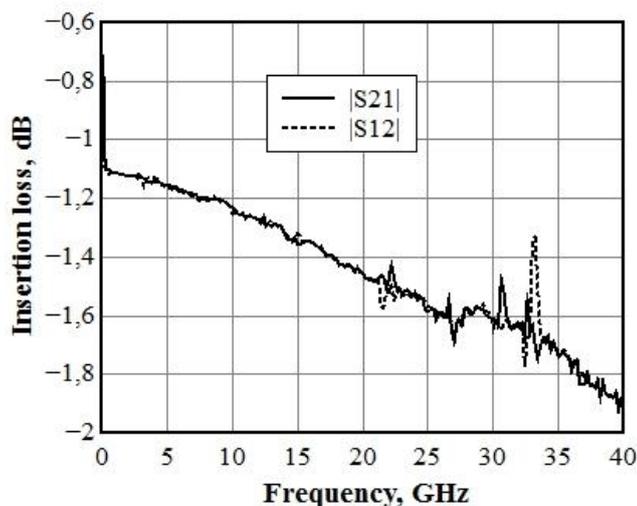


Fig. 9. MD902 insertion loss

Fig 10 shows the typical transfer characteristic with different frequencies of input signal.

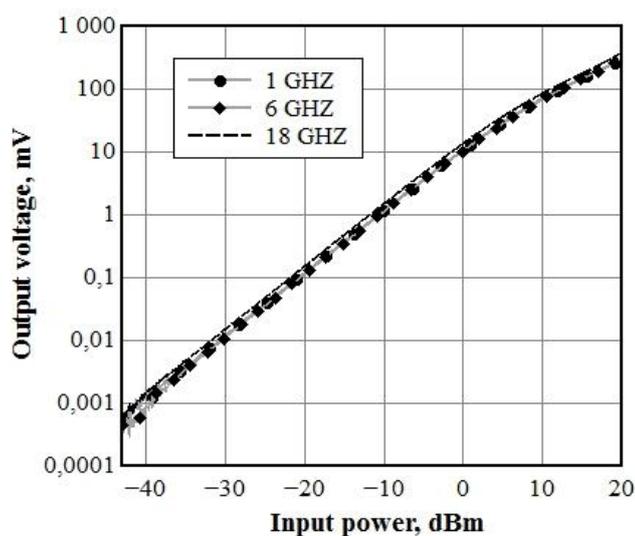


Fig. 10. MD902 MMIC transfer characteristics

## V. RESULTS AND DISCUSSION

The presented power detector MMIC's can be used as the main converting elements of power meters and detectors of microwave signals. Wide dynamic range and ability to operate up to 40 GHz provide the opportunity of applying these MMIC's in various fields of microwave technology.

## VI. CONCLUSION

Absorbed power detectors and directional power detector MMIC's have been designed, manufactured and measured. An extension of the square law detection area of the absorbed power detectors allows using MMIC for measuring complicated modulated signals, including signals GSM, CDMA, Wi-Fi, LTE

[5]. In addition, the MMIC can be used for impulse measuring with the possibility of setting up necessary video bandwidth.

## VII. ACKNOWLEDGEMENT

This work was supported by the Ministry of Education and Science of Russian Federation under contract 02.G25.31.0091.

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