

SWR meter for 144-1296 MHz bands

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PREFACE

During my experiments on UHF and lower microwave bands I faced a problem of accurate measurement of standing wave ratio coefficient. Commercial SWR-meters are rarely available or are not precise enough on these bands or are too expensive. Thus I decided to build my own SWR-meter. But what type? From my previous experiments with directional couplers I came to the conclusion that planar directional couplers are not suitable enough for this application. They suffer from several vices and their construction is pretty complicated. Thus I was searching an inspiration elsewhere. An idea of SWR-meter which I'm going to describe in this article belongs to Paul G7EYT. Refer to [1].

OVERALL CONCEPT

Schematic diagram of the SWR-meter is depicted in fig. 1. It can be seen that the SWR meter consists of three main parts: directional coupler, two detectors and display unit. Directional coupler is used to decouple a piece of energy from incident and reflected wave. Detectors convert this RF energy to direct current which is then displayed in the display unit. All these parts are further described in this chapters. Following chapters are showing my construction of the SWR meter.

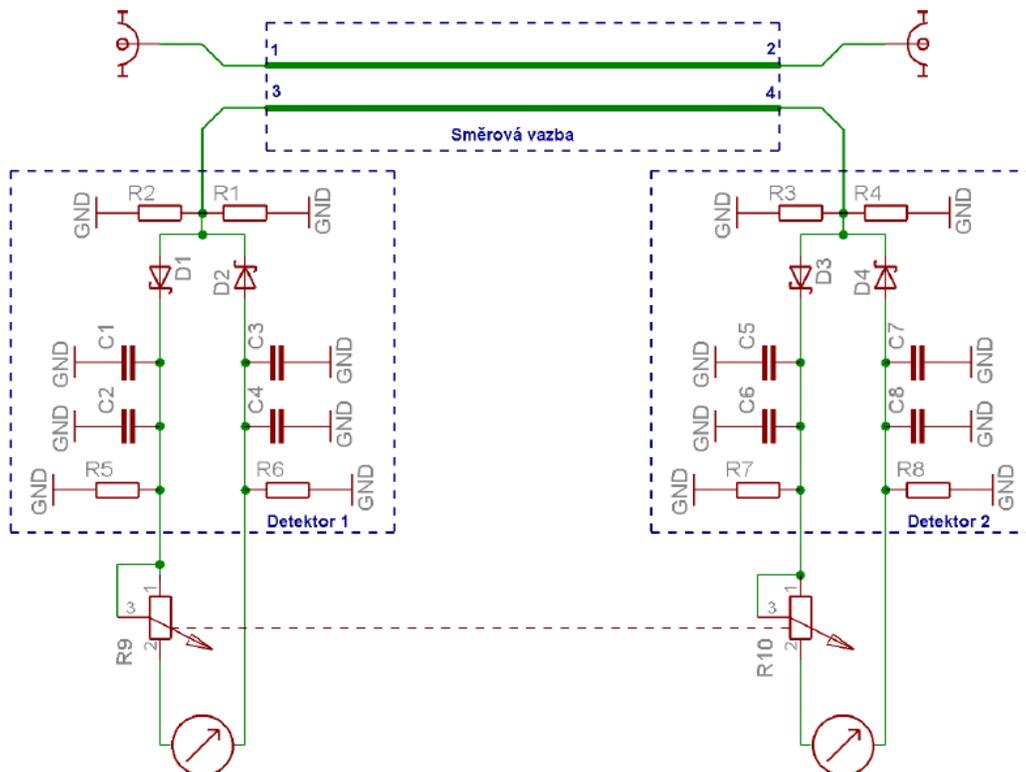


Fig. 1: SWR meter schematic diagram

Directional Coupler:

Directional coupler is made of two pieces of semirigid coaxial transmission line with outer diameter of 3,5mm. Both lines have a longitudinal gap filed in their shieldings so that the inner conductors are uncovered. The gaps are 60mm long and 1mm wide (Paul is using 30x2mm gap [1]. But his directional coupler is used for ISM band thus is half the length.) Both lines are pressed and soldered together so that the gaps overlap. This ensures coupling between both lines while keeping their characteristic impedances almost unchanged. Furthermore the coaxial concept ensures low radiation, good transmission between the connectors and coaxial coupler itself and thereby low insertion loss and low input and output reflection coefficients.

Detectors:

The detectors also follows Paul's concept [1]. The only difference is in used detection diodes. We can say that almost any microwave schottky diode with low barrier voltage can be used. I used some unknown type from discarded radiocommunication device. You can use a package with two integrated diodes (my case), two diodes in two packages or also a single diode (one-way rectifier) whose sensitivity is worse. We can estimate that the sensitivity of a single diode rectifier will be 6dB lower (half voltage) than in case of two-diode rectifier which is a significant value.

Furthermore both detectors should use the same detection diodes (same all components) to guarantee proper undistorted measurement.

Display unit:

In my construction I used widely used concept of two analogue meters with potentiometer for sensitivity adjustment. Meter connected to detector #1 is showing forward power, meter connected to detector #2 is showing reflected power. If we set the potentiometer so that the forward meter is showing full range the second meter (reflected power) will show us directly the SWR value (we must have the second meter calibrated to SWR).

FABRICATION OF DIRECTIONAL COUPLER

The directional coupler looks simple but its construction is not so easy and straightforward. I'll try to describe here some hints and recommendations.

The only suitable transmission line for this application is the „pipe“ semirigid coaxial line. The transmission line whose outer conductor is made of a tin-plated net known from standard flexible coaxials is not suitable. It is hard to file such a coaxial line.

First of all you have to prepare both pieces of semirigid. Cut them on an appropriate length (60mm for gap + length needed for connectors) and prepare all four ends for connector attachment. Do not mount the connectors right now, they will cool the transmission line while soldering the gaps together. Line up both coaxials, measure out 60mm in the middle for the gaps and bend slightly all ends. It is too risky to bend the lines after filing - you can deform them easily. Then solder the lines in the middle (if you also use an aluminium coaxial it is good to use a soldering liquid for Al) fix them in the vice and file the gaps in the middle. The dimensions of gaps should be approximately 60x1mm but based on my measurement this is not a strict requirement. The length should be 50 to 70mm if you want to use 144 to 1296MHz bands. The width of the gaps also isn't crucial. If you use wider gaps the inner conductors will be less spaced

from each other thereby reaching higher coupling coefficient. The SWR-meter will be then more sensitive and will work with weaker signals.

It looks like a small fimbriation at the edges of the gaps does not affect resulting parameters.

After both gaps are filed you can solder the lines together. Take care of good overlap of the gaps! Finally solder the connectors. My construction of the directional coupler is shown on figure 2.



Fig. 2: My construction of the directional coupler

FABRICATION OF THE DETECTORS

As it was stated above I used SMA male connectors for the coupling line. So the detectors are mounted on the female panel SMA connector. This way you can easily remove the detectors from the directional coupler and do some measurements is suitable measurement instruments are available.

The components of the detector are directly soldered on the connector body without any printed circuit board. This way all the parasitic parameters are minimized and we can assume that the detector will work fine on higher frequencies as well.

I used 0603 chip resistors and capacitors. (I guess Paul [1] is using 0805.) The values follow: C1, C3, C5, C7: 100pF; C2, C4, C6, C8: 560pF; R1, R2, R3, R4: 100; R5, R6, R7, R8: 10k; R9, R10: 22k/lin/stereo. As I mentioned earlier I used some unknown schottky diodes. I assume that a diode like BAT-15 will perform identically. The detector is depicted on figure 3.

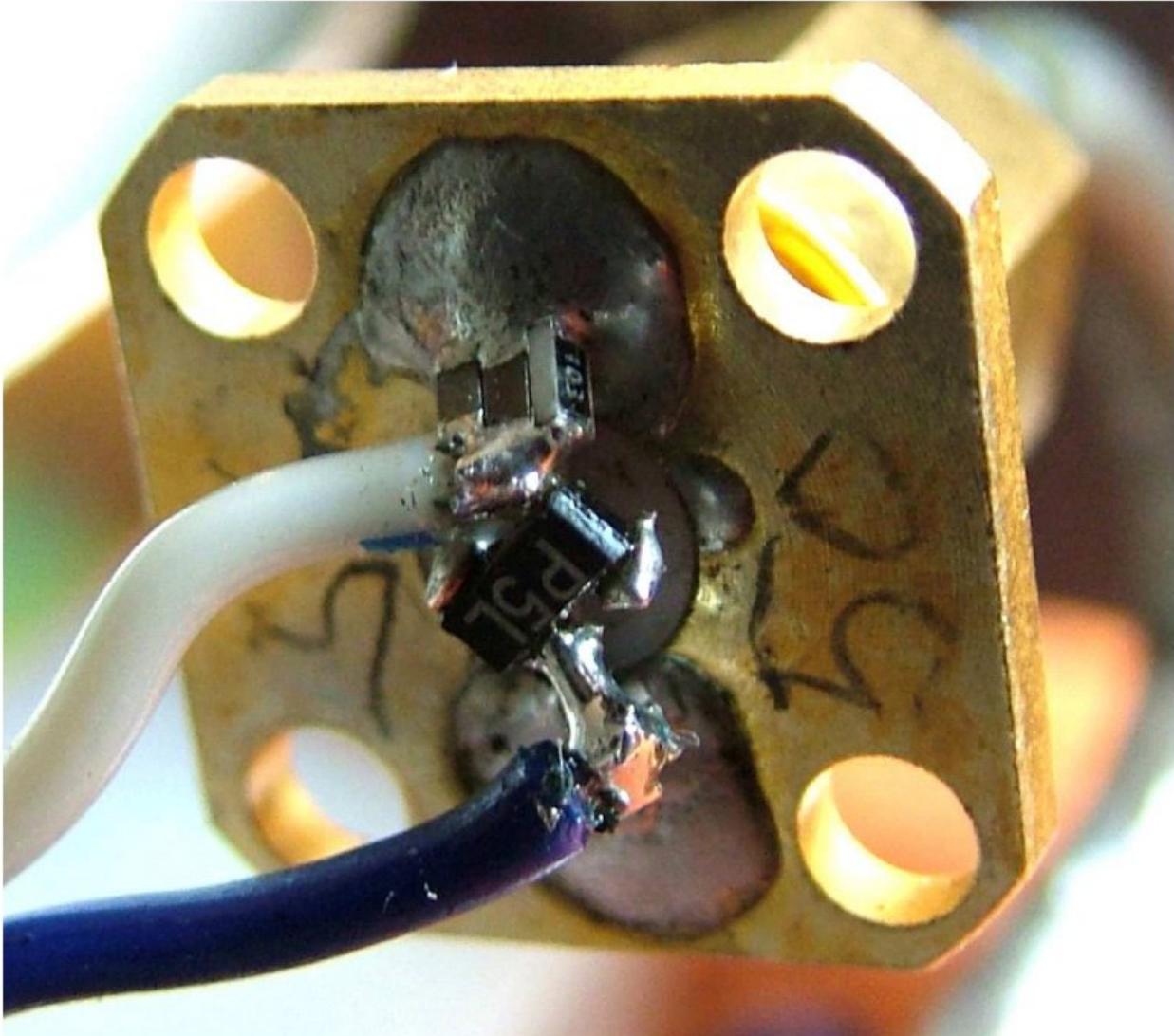


Fig. 3: The detector

MODIFICATION OF THE OLD SWR-METER

I mounted all the SWR meter into an „old“ unused commercial SWR-meter. So I reused the enclosure together with two analogue meters that were calibrated to SWR. My realization is shown on figures 4 and 5.

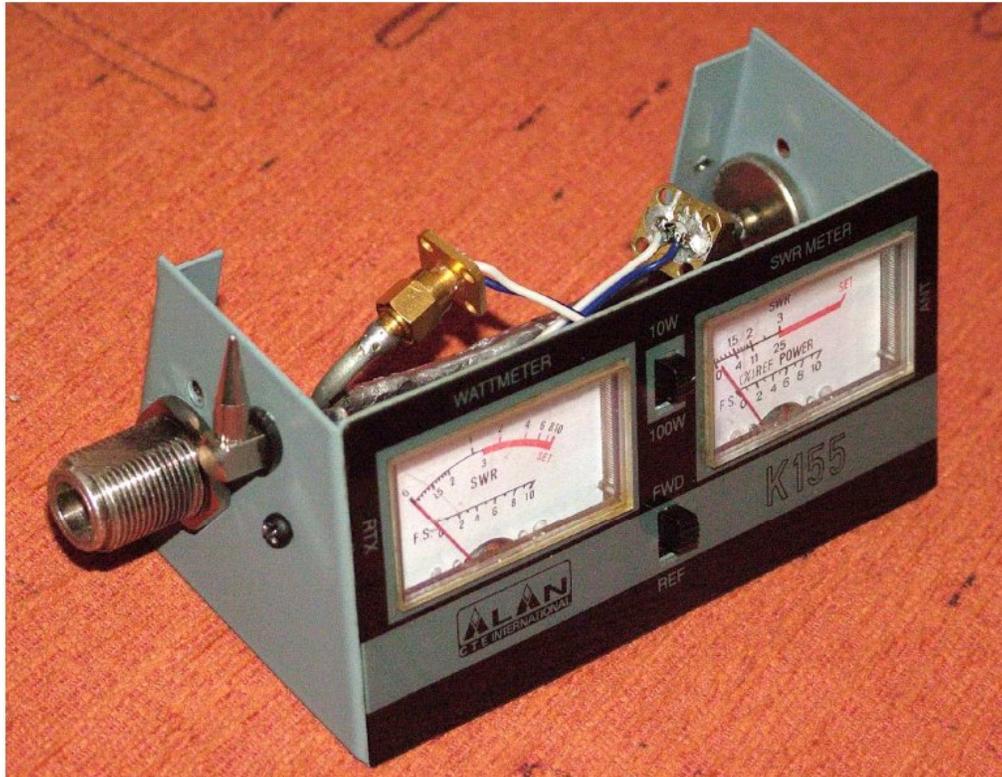


Fig. 4: Front view of my SWR-meter

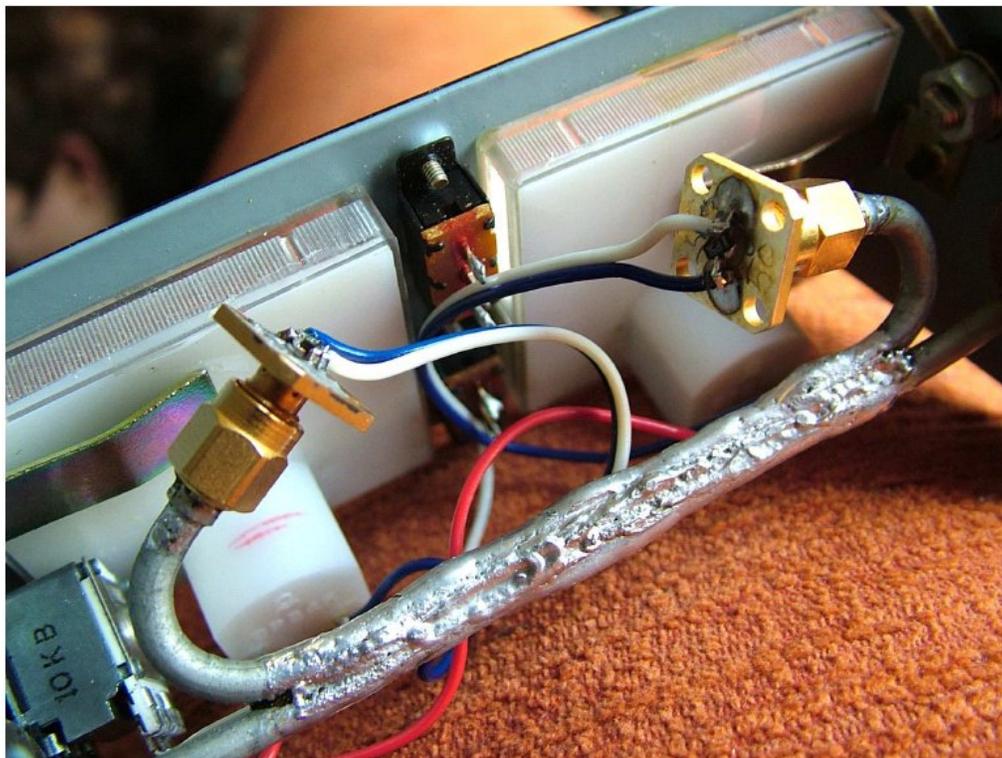


Fig. 5: Rear view into the SWR-meter interior

MEASURED PARAMETERS

Graph of coupling coefficient (desired transfer between the main and coupling transmission line – s_{31} from fig. 1) and isolation (undesired transfer between the main and coupling transmission line – s_{41} from fig. 1) is captured at figures 6 and 7. It is desired that the difference between the isolation and coupling coefficient (thus the directivity) is as high as possible because this value determines the lower level of SWR that the device is able to measure without significant error. As it can be seen from graphs 6 and 7 the value of directivity at amateur bands is:

- 144 MHz: 26,5 dB
- 432 MHz: 24,6 dB
- 1296 MHz: 19,4 dB.

Because the desired signal detected on the coupling line should be stronger than the undesired one, one can expect that the lower limit of reflection coefficient indicated without significant error is -20,5 dB for 144 MHz, -18,6 dB for 432 MHz and -13,4 dB for 1296 MHz. In terms of SWR this means 1,21 for 144 MHz, 1,27 for 432 MHz and 1,54 for 1296 MHz. If we measure SWR that is lower than these values the error becomes unacceptable. On frequencies above 1,5 GHz the value of directivity is too low and the SWR-meter can not be used here. If you want to use the SWR-meter on higher frequencies you have to fabricate a directional coupler with shorter gap.

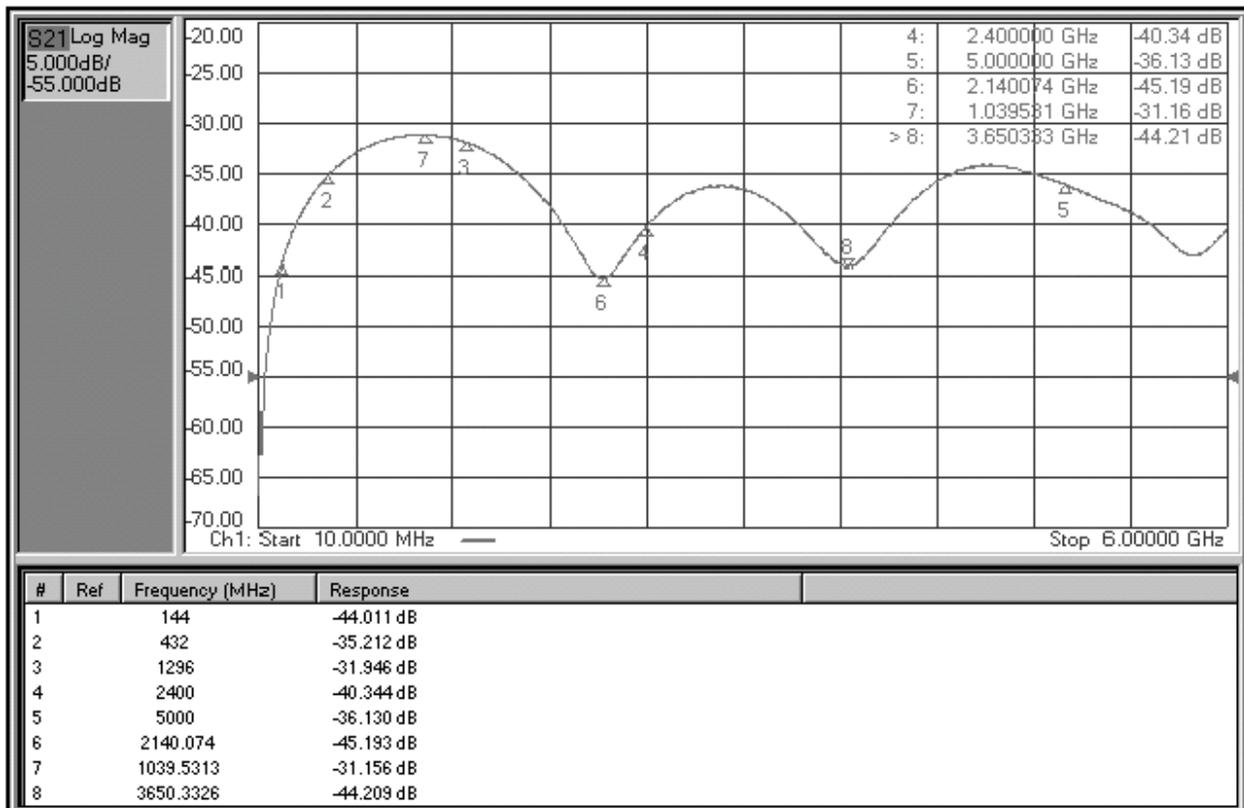


Fig. 6: Coupling coefficient (s_{31})

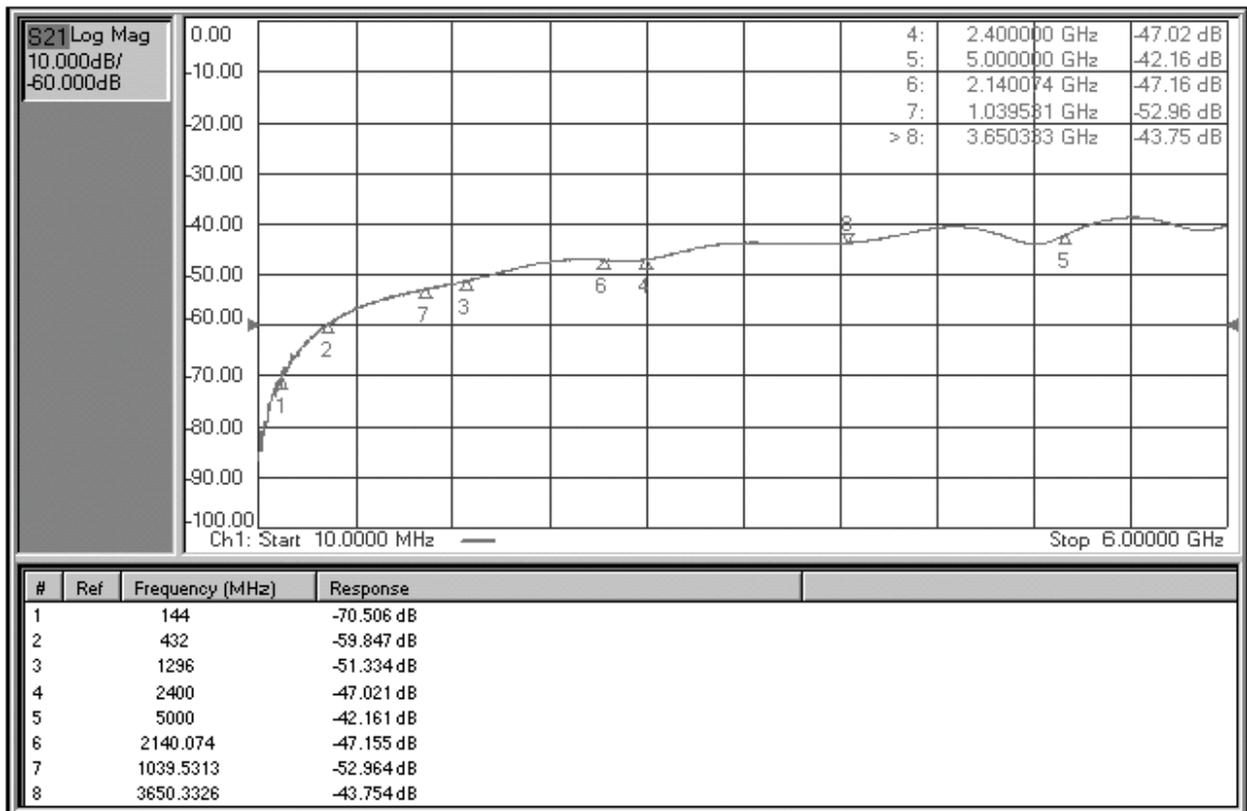


Fig. 7: Isolation (S_{41})

As for the lower power limit of the SWR-meter the transfer characteristic of used detectors must be known. In my case this is captured in table 1.

frekvence [MHz]	budící výkon [dBm]						
	-10	-5	0	5	10	15	20
144	62	156	356	752	1483	2817	5223
432	59	150	343	725	1434	2727	5065
1296	55	140	322	683	1353	2586	4844
2400	54	137	320	676	1349	2593	5281
5000	65	159	348	738	1455	2690	4655

Tab. 1: Transfer characteristics of the detector (first row: *input power* in dBm, first column: *frequency* in MHz)

Supposing the resistance of used analogue meter to be in range of 400 to 1000 ohm (full scale is excited by 100uA current) that a voltage as low as 60 mV can excite the meter to its full scale. Based on table 1 this voltage can be generated by a signal whose power is -10dBm. If we further take into consideration figure 6 than we can make a conclusion that the SWR-meter should be capable to fully operate with signals as low as 35 dBm (~ 3 W) at 144 MHz, 25 dBm ($\sim 0,3$ W) at 432 MHz and 22 dBm ($\sim 0,15$ W) at 1296 MHz. The truth is that the reality has proven slightly higher values - e.g. 1 W at 432 MHz.

As for the upper power limit this is given by reverse voltage of diode used in the detectors. If we suppose this value to be 4V (example for BAT-15) and if we further take into

consideration table 1 than we can deduce that the detector can handle signals up to 22dBm approximately. Recalculated to the input of the directional coupler it makes 66dBm (approximately 4kW) for 144MHz, 57dBm (500W) for 432 MHz and 54dBm (~250W) for 1296MHz. But it is doubtful if the rest of the SWR-meter will be able to withstand such a high power (4kW).

Please notice that all introduced calculations are just only rough estimates.

Further measurements are showing that the insertion loss of the SWR-meter is well below 0,2dB for frequencies up to 1,8GHz and reflection coefficient is better than -25dB for frequencies up to 2GHz. More measurements can be found in [2].

CONCLUSION

This article described a construction of an easy-to-build SWR-meter that is suitable mainly for UHF and SHF frequencies. Based on measured data it can be seen that such an SWR-meter is fully sufficient for ham radio purposes.

I wish good luck to all of you that decided to build this SWR-meter.

73, Honza.

USED LITERATURE

[1] <http://www.frars.org.uk/cgi-bin/render.pl?pageid=1085>

[2] www.radioamater.cz nebo <http://ok1tic.nagano.cz>