# The 36 -360 GHz range resonator spectrometer for investigations of solid, liquid and gaseous dielectrics and metals reflectivity

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## Abstract:

The precise spectrometer on the base of open resonator technique, for solid, liquid and gas dielectrics investigations and for metal reflectivity investigations at MM and SubMM ranges and at the temperatures 20-650°C is presented.
The uniform series of radiation sources of the 36-360 GHz (6 sub-bands) on the BWO base, with the minimum frequency step = 0.3 Hz was created. The sources are used for exiting the measuring resonator and for precise recording its resonance curve.

## Introduction

The present work is the development of the previous ones [1,2] for advancing the resonator spectrometer for investigations of metals reflectivity [3] and the ultra low absorption in modern dielectrics (like CVD-Diamond and Silicon [5,6]) in SubMM range.
This spectrometer is especially suitable for investigations of absorption in real atmosphere including absorption in molecular spectral lines and continuum absorption. [1,4]
The advanced spectrometer works in all MM range and partly in SubMM range. Its frequency range is 36-360 GHz!

## Apparatus

The simplified block diagram of the apparatus is presented in Figure 1. The open Fabry-Perot resonator is used for dielectric and atmosphere measurements. The resonator length is 250 – 400 mm, the quality factor is $\sim 10^6$.
Teflon film with the thickness 6 - 40 μm is used as a resonator coupling element with generator and detector. This type of excitation of resonator permits one to excite mainly the fundamental type of oscillations. Besides it is rather simple to change the coupling coefficient by changing film thickness depending on the losses in the sample.

The uniform set of radiation sources in the frequency range 36-360 GHz on the base of BWO, with the minimum frequency step = 0.3 Hz were created for the measuring resonator excitation and for precise recording its resonance curve. The frequency stability is determined by Quartz or Rubidium reference frequency standard.

For resonator excitation and for the PPL system operation the uniform set (6 units) of waveguide-quasi-optical transmission lines were made and successfully used in the apparatus.
The radiation sources can be replaced together with all quasi-optical transmission lines including attenuators, directional couplers, beam splitters, horns, mixers and detectors.

The synthesized frequency radiation source employs a BWO based generator which was stabilized by a phase lock-in loop with the use of two reference synthesizers: a microwave synthesizer defining the central frequency and a fast synthesizer for a precise fast scanning of the BWO frequency around the chosen central frequency. Fast synthesizer provides digital frequency scanning without the loss of the phase of oscillations (without phase jumps while frequency switching). The time of one upward-backward frequency scan is ~15 ms.
The resonator curve width determination includes the fitting of its shape to the Lorentzian profile. The achieved accuracy of a resonator curve width measurements is ~ 20 Hz after ~ 500 averaging of scans at low frequencies and ~ 300 Hz at the high frequencies.
The sensitivity in the terms of the absorption coefficient for gas, defined for 20-Hz resonance width measurement accuracy constitutes ~ 0.002 dB/km ($\sim 4\times10^{-9}$ cm$^{-1}$).
This accuracy corresponds to the Loss tangent value $< 10^{-7}$ for the diamond plate with ~ 0.5 mm thickness. (At present the diamond is the material with the minimum absorption.)
The current possibilities of the installation for atmospheric measurements are: wide band record of atmosphere absorption by the frequency step of 300-500 MHz; the measurement of absolute absorption at any frequencies by changing the resonator length.

The advance in SubMM range was made on the base of rather powerful BWO (type OB-24 and OB-30 with 50-100 mW of output power) with frequency range 170-240 GHz and 220-380 GHz. They are manufactured as not packetized generators so the special design of rather inexpensive magnet system and adjustment construction were elaborated and successfully applied.
(The total weight of the magnet system is less than 5 kg and the volume is less than 0.7 litre Fig.2.).
It is necessary to mentioned that BWO has not any of resonance elements (so the working frequency range is extremely wide) and it is necessary to use the isolator with at least 20 dB attenuation for precise recording of the resonance curve of high-quality resonator. There are no the waveguide isolator in the SubMM range and the use of quasi-optical isolator [8] is rather complicated way.
So to avoid these difficulties we took out all isolators but have used the new PPL system with extended frequency range of output amplifier. By this way we have got additional several dB of signal increasing and simplified the construction of the excitation systems.
It was checked before that the DC amplifier at the PLL output with extended frequency range up to ~ 70 MHz (at the unit level of amplification) is quite enough for excluding of any influence of the resonator the BWO operation.)

For the signal detection at SubMM we use planar diode placed in the specially designed waveguide box with the sizes 0.55×1.1 mm. For MM waves we use standard commercial detectors with corresponding waveguides.

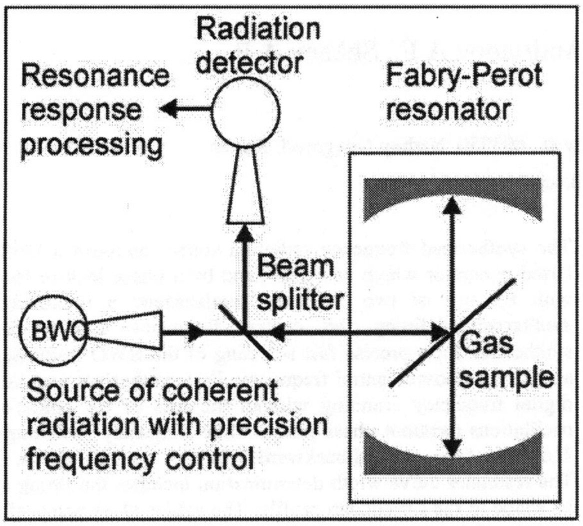


Fig.1. The simplified block diagram of the apparatus.

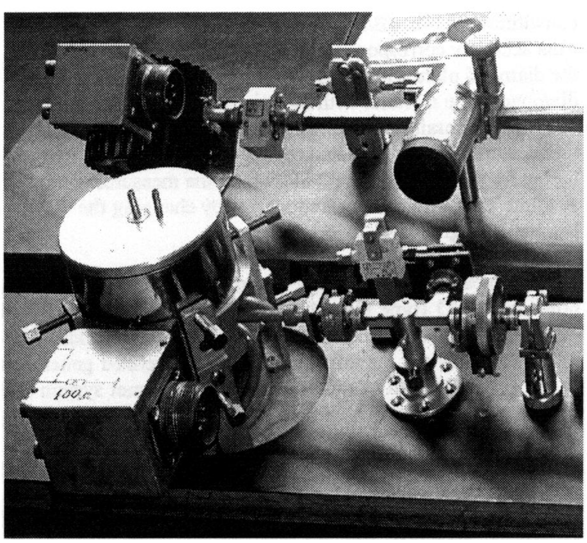

Fig.2. The photo of commercially packetized (behind) and homemade packetized BWO generators (OB-86 and OB-30 correspondingly) with microwave parts of the PLL system.

## Conclusion

The precise spectrometer on the base of open resonator technique for all MM and partly for SubMM ranges was designed and tested.
The wide frequency and temperatures investigations of the CVD-Diamond and Diamond like materials were performed to understand the absorption mechanism. [Parshin et al., this Conference report].

The reflectivity investigations of antennas and mirrors were made in MM and SubMM ranges [Parshin et al., this Conference report].
We are currently working on the wide band atmosphere absorption investigations.

## Present activities and plans

The set up is nowadays at the stage of modification in the direction of maximum possible excluding the human factors influence on the results of measuring. In this direction the maximum possible measuring process autoimmunization is under development.
The protection system against the atmosphere influence at SubMM range is also at the stage of construction.
This protection system will permit also investigation in normal laboratory atmosphere as well as at the atmospheric conditions of upper troposphere and stratosphere.

## Acknowledgment

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