# DUAL OUTPUT STABILIZED GUNN OSCILLATOR FOR FINLINES

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## ABSTRACT

***A dual output Gunn oscillator for use in an integrated K-band network analyzer extender has been developed. It is stabilized using a dielectric resonator in a unique hybrid configuration with transmission type cavity behaviour. Both output ports offer 15 dBm power at 16 GHz.***

## INTRODUCTION

In order to extend the frequency range of a microwave network analyzer, a symmetrical arrangement of two harmonically or sub-harmonically pumped mixers for the test- and the reference-channel can be used (Fig.1). This concept is general for all network analyzer principles which use electrically balanced arrangements. For ideal symmetry, both mixers must be pumped by identical local oscillator (LO) signals, which therefore are derived from one single LO using a power splitter. To avoid crosstalk between reference and test channel, some means are necessary to reject the whole range of measured frequencies (RF) and intermediate frequencies (IF) as well. This function can be realized by either isolators or bandpass filters with large rejection bandwidth, and is depicted as the blocks "REJ" in fig.1.

With exception of the high millimeter wave bands, the IF frequency range obtained with one fixed LO frequency can be handled by the basic microwave analyzer, which mostly covers at least the 2..18 GHz range. For reproducibility the LO should have long-term stability and possess high spectral purity to avoid excess noise and thereby reduced dynamic range.

To achieve an inexpensive, reproducable solution, which is also usable in the mm-wave range, finline was chosen as the wave-guiding structure. The LO shall be stabilized by a dielectric resonator. Thus all components, namely the LO (including the bias circuit), the bandpass filters, and the double balanced mixers of /1/ can be integrated on a single RT-duroid substrate.

## CHOICE OF THE STABILIZATION CIRCUIT CONFIGURATION

A microwave oscillator can be stabilized by coupling it to a high-Q resonator. This resonator, also referred to as cavity, determines the stability of the total system to a large extent at the sacrifice of output power. The following properties should be comprised in the present oscillator design:

- high external Q-factor $Q_L$
- high temperature and long-term stability
- single tuned behaviour
- high and stable output power

Tunability and related power variations, together with variations of $Q_L$ over the tuning range, play a secondary role in this application.

Three basic configurations are commonly used for the direct stabilization of negative resistance oscillators (Fig.2): The reflection type (Fig.2a), the reaction type (Fig.2b), and the transmission type (Fig.2c) configuration. Considering the results of /2/, we recognize that the reaction type and the transmission type resonator configurations are suited equally well for this application. The reflection type cavity is ruled out by the low achievable loaded Q-factor. The reaction type cavity allows the largest output power for a given $Q_L$, whereas the transmission type cavity is less sensitive to changes of the other circuit parameters, including the voltage-dependent device susceptance. This is an indirect consequence of its large tuning range. However, the realization of a transmission type cavity using a dielectric resonator and finline seems to be rather impractical, especially since a well defined damping resistor in parallel to the coupling is needed to achieve a single tuned characteristic /2/. Therefore we decided to use a reaction type resonator configuration.

## SPECIFIC CONSIDERATIONS FOR STABLE FINLINE OSCILLATORS

One fundamental impediment for realizing a single tuned performance over a wide frequency range is the non-TEM characteristic of the finline as wave-guiding structure. Furthermore, the use of band-pass-filters as rejection elements gives rise to large reflections in the vicinity of the operation frequency. Since these reflections or those of far--away transitions to waveguides (that are below cutoff at lower frequencies) cause unwanted loops in the load admittance as seen from the active device, appropriate damping must be ensured by additional means.

Another crucial point is, that housings commonly used for Gunn devices are not well suited for direct mounting inside a finline slot. This way of mounting leads to extensive parasitics and poor mechanical stability, which is a prerequisite for temperature- and long-term-stable operation.

A very promising alternative approach to solve the mounting problem may be borrowed from our quasi-H-plane circulator /3/ and was investigated in the form of fig.3. The cross-sectional view shows the Gunn device, backed by a waveguide below cutoff, and mounted perpendicular to the substrate in a reduced width section of the finline. It exhibits a strong coupling to the eccentric slot as elucidated by the electric field lines, and can readily be biased by a structure integrated on the lower side of the substrate. Unfortunately the implementation of the aforementioned additional damping turned out to be very difficult. Furthermore, this structure does not allow to mount a reaction cavity due to the lack of space. Therefore it has not been applied in the final device.

The aforementioned difficulties could be overcome by using a modified symmetrical microstrip to finline transition as a simple power divider, and mounting the Gunn device in a unique way in the microstrip part of the hybrid structure.

## MOUNTING OF THE GUNN DEVICE

The standard way to mount a Gunn device into a microstrip circuit is to solder it to an open end at one edge of the substrate /4/ or to insert it through a hole. To avoid strong parasitic effects, the substrate thickness should match the height of the ceramic ring of the device and should have a permittivity of about 6. Both properties are in conflict with low-loss requirements for the finline bandpass filters planned later on.

Instead, a new configuration for rather thin (0.254 mm), low permittivity ($\varepsilon_r$ = 2.22) substrates was developed, which makes use of a short section of evanescent waveguide and some additional low permittivity dielectric below the substrate to match the strip width to the diode's cap diameter. This avoids excessive stray capacitance (Fig.4a..c). The ground metallization has been removed in the area circumscribed by the broken line. This mounting technique turned out to have surprisingly low parasitics and allowed operation of X-band Gunn devices up to 17 GHz.

## OPTIMUM ARRANGEMENT OF DIELECTRIC RESONATOR AND TRANSITION TO FINLINE

The use of a dielectric resonator (DR) as reaction type cavity with microstrip is well known. As explained above, we need an additional TEM-coupled load and may use the remaining microstrip port for this purpose. Instead of placing the resonator between the Gunn device and the slot, which gives rise to unfavourable losses in the microstrip load, we place it behind the slot as seen from the Gunn device. Now the transition must be purposefully degraded to maintain the oscillation condition. This can be done by a conductive strip across the slot, which is centered to the microstrip.

With proper adjustment of the distance l between resonator and slot (Fig.5), it is even possible to get a transmission type behaviour, i.e. a narrow transmitted band inside a broad band of relatively small transmission. This is achieved with a spacing l of a little more than a half wavelength. Then the input impedance of the microstrip line as seen from the slot is capacitive and partly compensates the inductance of the strip across the slot. The half wavelength is inserted to avoid direct coupling between DR and slot, which would cause an asymmetric power distribution to the finline ports. The transmission type behaviour should additionally decrease PM noise at sideband frequencies beyond the hold-in range of the tuned oscillator /5/.

The complete circuit may be represented by the e.c. of fig. 6. The calculated load line, as seen from the device terminals, is drawn in the Smith chart of fig. 7 over a frequency range of 7...25 GHz. It has been optimized to match the measured device line, which is located inside the hatched area of fig. 7.

## REALIZATION AND EXPERIMENTAL RESULTS

The layout of the complete oscillator circuit for use in a K-band network analyzer extender with 16 GHz LO frequency is shown in fig. 8. The DR is placed on a polystyrene holder and overlaps the microstrip. The dummy load is connected via an SMA connector, which offers an auxiliary low power output. Dolph-Chebyshev tapers /6/ are used as transitions to standard WR62 waveguide. Using a 100 mW X-band Gunn device (MA 49107 from MA-COM), 30 mW output power is available at each of the two equivalent ports and 8 mW at the auxiliary port. Up to now, only qualitative measurements concerning stability have been done. Fig. 9 shows a comparison between unstabilized (u) and stabilized (s) spectra, using an open stub resonator in case (u). Fig. 10 shows the oscillation frequency and output power over the bias voltage. The oscillator is absolutely stable in the sense that oscillation is ceasing when the dielectric resonator is removed.


## ACKNOWLEDGEMENT

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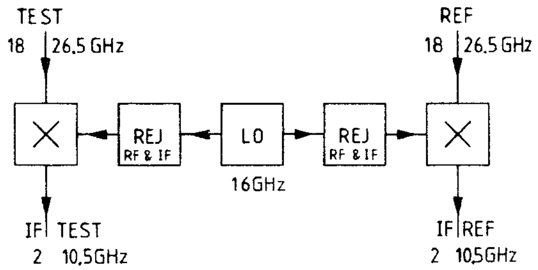


***Fig. 1:*** ***Block diagram of network analyzer extender***

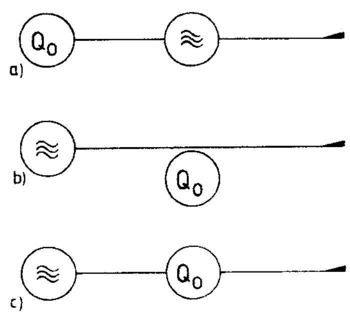


***Fig. 2:*** ***Stabilization of oscillators by external resonator***
***a) reflection type***
***b) reaction type***
***c) transmission type***

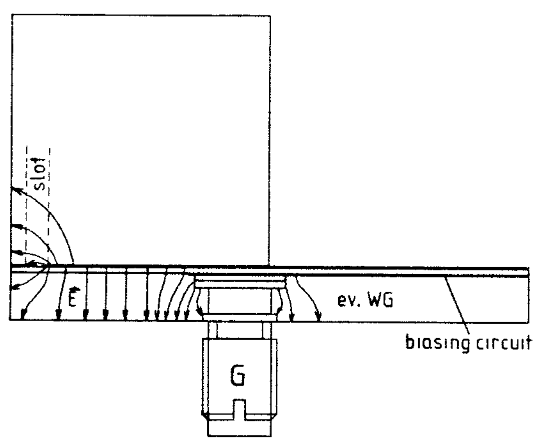


***Fig. 3:*** ***Oscillator coupled via eccentric finline***

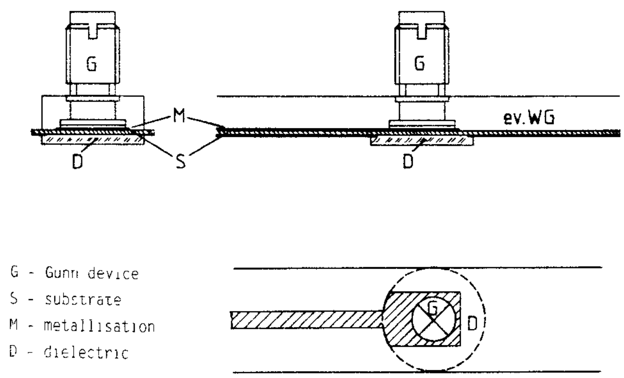


***Fig. 4:*** ***Hybrid oscillator: coupling of the Gunn device to the microstrip***

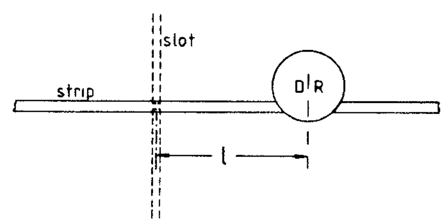


***Fig. 5:*** ***Hybrid oscillator: microstrip to finline transition and dielectric resonator***

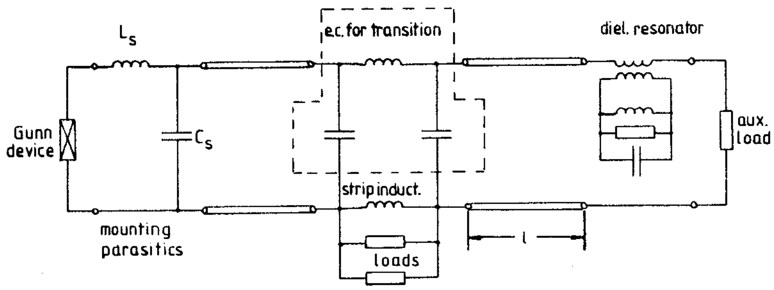


*__Fig. 6:__* ***Hybrid oscillator: equivalent circuit***

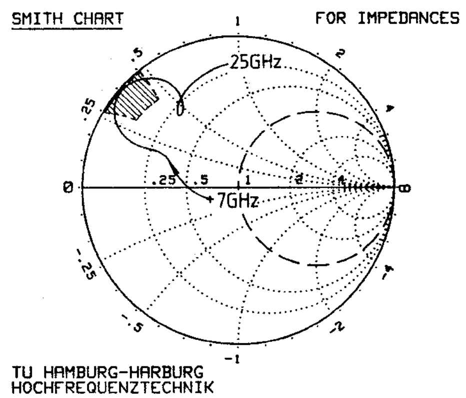


*__Fig. 7:__* ***Hybrid oscillator: device line and load line***

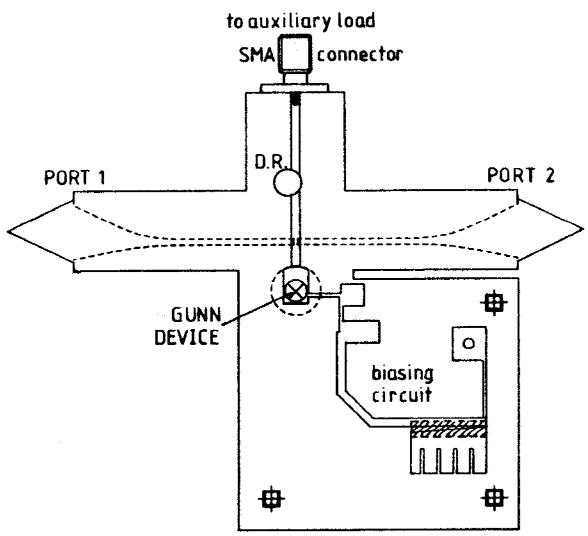


*__Fig. 8:__* ***Layout of the hybrid oscillator (lower surface dashed lines)***

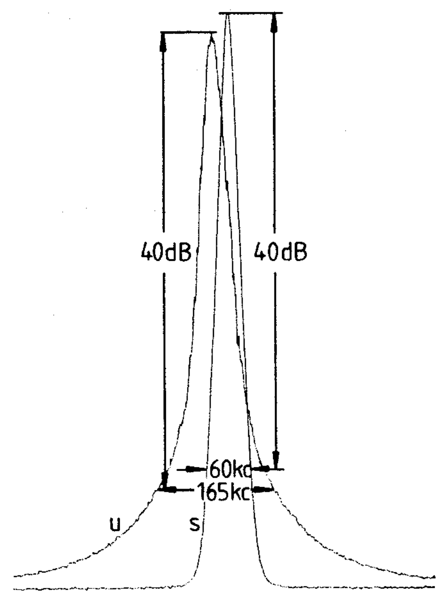


*__Fig. 9:__* ***Spectrum of hybrid oscillator***
***u) unstabilized (microstrip open stub resonator)***
***s) DR stabilized***

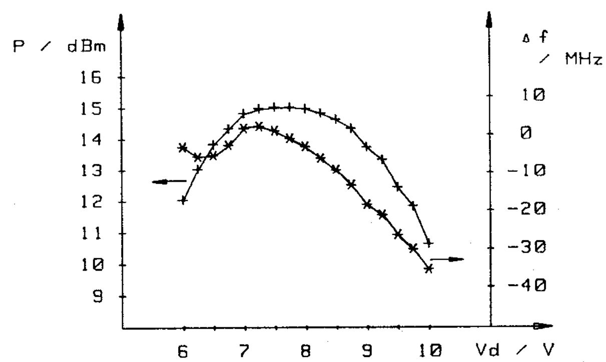


*__Fig. 10:__* ***Hybrid oscillator: performance versus bias voltage***