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Spectrum Analyser 0 to 1750 MHz

1. SPECTRUM ANALYZER DESIGN

Wideband (panoramic) receivers and RF spectrum analysers are usually designed as multiple-conversion receivers with the first IF above the maximum input-signal frequency. Amateur designs are mainly limited by the performance of the VCO used for the first frequency conversion. The 2-4 GHz VCO presented in [1] and [2] allows the design of a simple spectrum analyser covering the frequency range 0 to 1750 MHz in a single span.

The resulting spectrum-analyser block diagram, shown on Fig.1, was already briefly described in [1] and [2], although only the microwave VCOs were described in detail. In this article the remaining building blocks of the above mentioned spectrum analyser will be described in detail, as well as the overall assembly and tuning of the completed instrument.

As already mentioned in [1] and [2], the described spectrum analyser is a triple-conversion receiver with the corresponding IFs around 2.1 GHz, 70 MHz and 10 MHz. Since both the first LO and the second LO are VCOs, the first IF may be made variable. This may be useful to shift some spurious responses of the first mixer in some difficult measurements

The described spectrum analyser is designed to use a standard XY oscilloscope display. Additional control signals are provided to drive different displays as well as frame memories, storage normalisers, marker generators and/or trigger frequency counters. The outputs of both VCOs are also made available to drive a tracking generator or a frequency counter. Some of these additional circuits will be described in future articles.

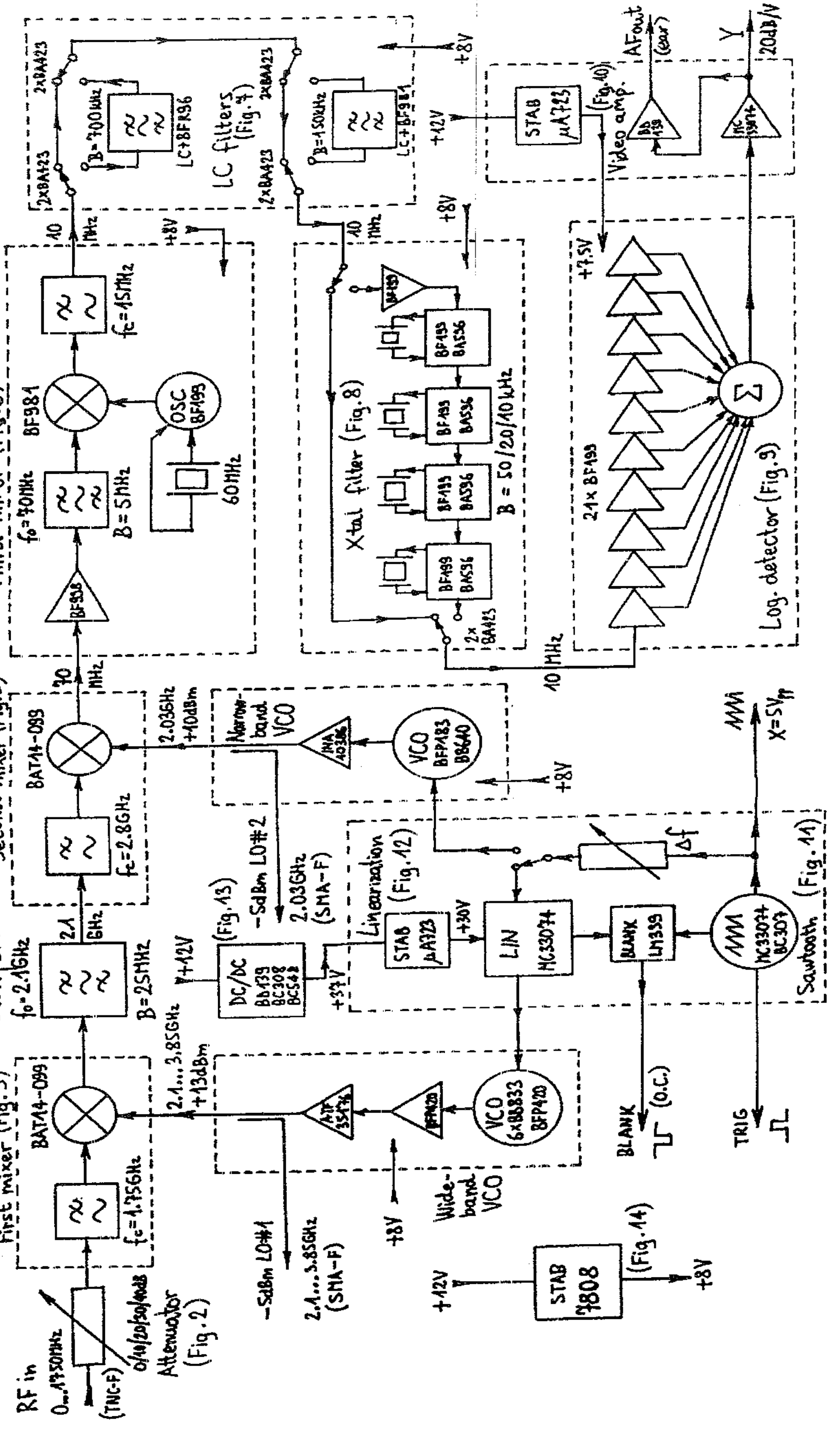

Fig.1: Spectrum Analyser Block Diagram

2. INPUT ATTENUATOR

The input attenuator is a simple yet important part of a spectrum analyser. The main function of the input attenuator is reducing the signal level to avoid overdriving the first mixer. The input attenuator should therefore only include very linear components like resistors and mechanical switches.

The basic attenuator circuit is a simple "PI" or "T" resistor network. The resistor values are selected both for the desired attenuation value and input/output impedance matching. Since a "PI" or "T" network contains three independent resistors, all three quantities can be adjusted independently within certain limits: attenuation, input impedance and output impedance.

Generally speaking, attenuators can be built for any frequency provided that the resistors (and switches) are sufficiently small with respect to the wavelength and/or are designed as parts of transmission lines with carefully controlled characteristic impedances. Professional attenuators, both fixed and adjustable, are available for frequencies up to 18 GHz and beyond, depending mainly on the coaxial connectors.

On the other hand, it is much more difficult to build good microwave attenuators from standard electronic components. Resistors with wire leads are only useful up to about 500 MHz. SMD resistors are much better due to their smaller size and can be used up to at least 5 GHz. Finding suitable mechanical switches for microwave frequencies is even more difficult.

The circuit diagram of the attenuator, shown on Fig.2, therefore can not tell much about the microwave performance of the circuit. The attenuator includes four identical "PI" networks and four DPDT switches. This design allows a nominal attenuation of 0dB to -40dB in 10dB steps.

Standard SMD resistors of the size 0805 or smaller are certainly good enough for a 2 GHz spectrum analyser. It is much more difficult to find suitable DPDT switches with low parasitics. In the prototypes standard miniature DPDT toggle switches were used. The resulting frequency response was compensated with 1pF SMD capacitors soldered across the 68ohm resistors. Finally, the toggle switches were installed between two small printed-circuit boards to keep their impedance closer to 50Ω (to be described later in this article).

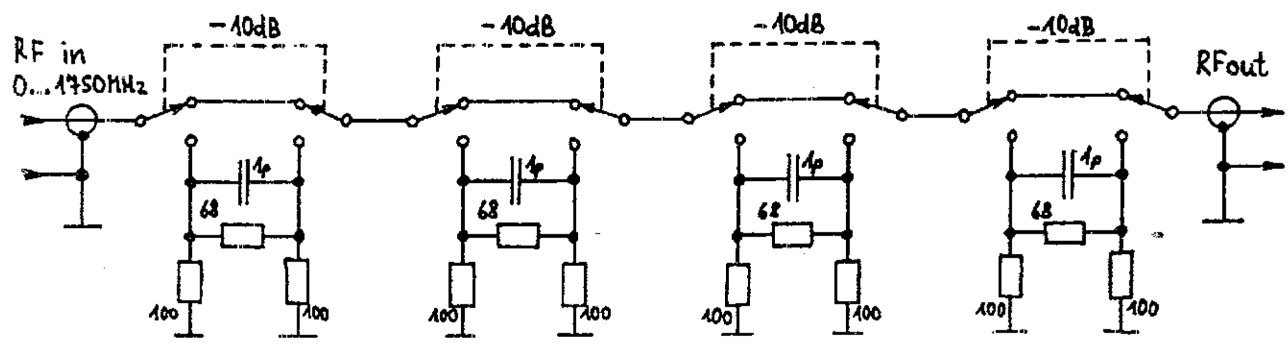

Fig.2: Input Attenuator

A careful construction together with some compensation capacitors allows to keep the frequency response of the attenuator within +/-1dB for frequencies up to 1 GHz and within +/-2dB for frequencies up to 2 GHz from the nominal attenuation value. Since the maximum power dissipation of SMD resistors is 1/8W, the maximum input power to the described attenuator is about 250mW (+24dBm). At the maximum attenuation value of -40dB this means -16dBm at the first mixer input.

Of course additional (external) high-power attenuators or couplers are required for transmitter measurements. The input attenuator of a spectrum analyser is only intended for fine adjustments of the input signal level and/or finding the source of some signals: real signals or unwanted mixing products in the spectrum analyser?

Finally, the described attenuator does not include any protection against DC voltages that may be present in some RF circuits!

3.
FIRST MIXER

The dynamic range of any receiver depends mainly on the performance of the first mixer. The low end of the dynamic range is defined by the mixer noise figure (insertion loss) while the high end of the dynamic range is defined by the mixer distortion (intermodulation). Further, the first mixer of a spectrum analyser may be easily destroyed by high RF levels, DC voltages and even static discharges on the input connector.

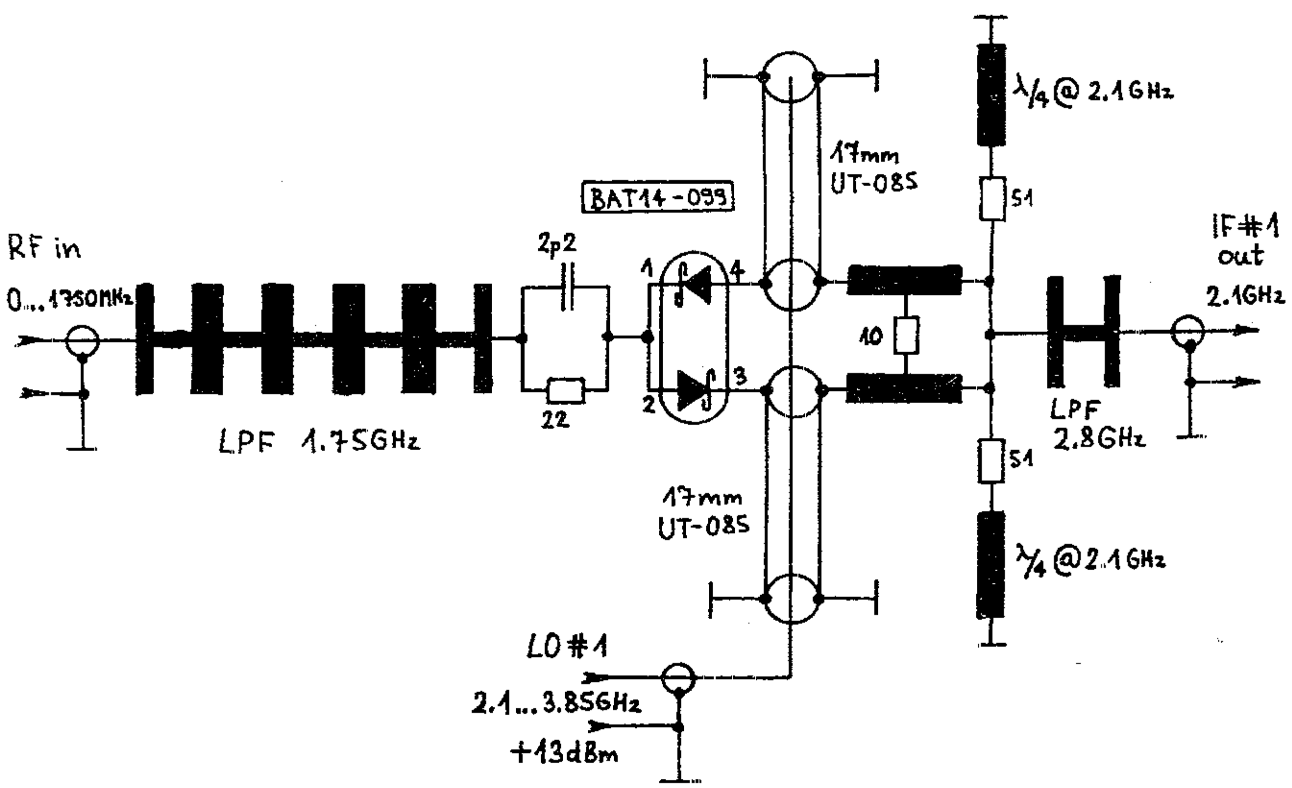

Fig.3: First Mixer

The first mixer of a spectrum analyser should therefore both provide the best possible dynamic range and at the same time allow quick and inexpensive repair in the case of damage. The latter requirement makes commercially-available, doubly-balanced mixers with Schottky quads and ferrite balancing transformers unpractical.

The described spectrum analyser is therefore using an inexpensive double Schottky diode BAT14-099 in the first mixer. The balun for the local oscillator is built from UT-085 semi-rigid cable, as shown on Fig.3. A completely symmetrical construction allows a balancing of at least 30dB without any tuning and more than 45dB by adding small drops of solder in the circuit. Of course the symmetry of commercially-built mixers can not be improved since the latter are built in hermetically-sealed packages.

A good mixer symmetry is required for many reasons. A balanced mixer prevents the oscillator noise from getting directly in the first IF. Further, some unwanted mixing products are suppressed in a balanced mixer. In the case of a spectrum analyser it is especially important to suppress second-order distortion products, so that the spectrum analyser can be used to accurately measure the suppression of the second harmonic in radio transmitters.

The first mixer module includes a microstrip lowpass filter with the cutoff frequency of about 1.75 GHz. The latter should suppress unwanted responses of the spectrum analyser in the microwave frequency range. Its insertion loss amounts to about 45dB at the first IF around 2.1 GHz and becomes even higher at higher frequencies. The lowpass is followed by a RC network to slightly compensate the slow decay of the sensitivity at frequencies above 1GHz.

The mixer diode BAT14-099 is followed by several components to provide impedance matching and suppression of unwanted resonances. For example, the open end of the UT-085 balun is also used as a coupling capacitor. The two 51Ω resistors and corresponding quarter-wavelength lines provide a termination for the image frequency and other unwanted mixing products, reflected by the 2.8 GHz lowpass and the following cavity bandpass filter.

4. CAVITY BANDPASS FILTER

In all wideband receivers, the first mixer should be followed by the best possible bandpass filter. In HF receivers covering 0....30 MHz, a 15 kHz wide crystal filter is usually used in the first IF around 45 MHz or 70 MHz. Considering the first IF the described spectrum analyser at 2.1 GHz, a cavity bandpass filter is the only technology that provides both high selectivity and low insertion loss.

Microwave cavities are electrically simple to describe, but usually require lots of precision mechanical work and special tools for manufacturing. Several efforts were spent in finding a reproducible cavity-filter design, made from standard materials using only simple mechanical tools.