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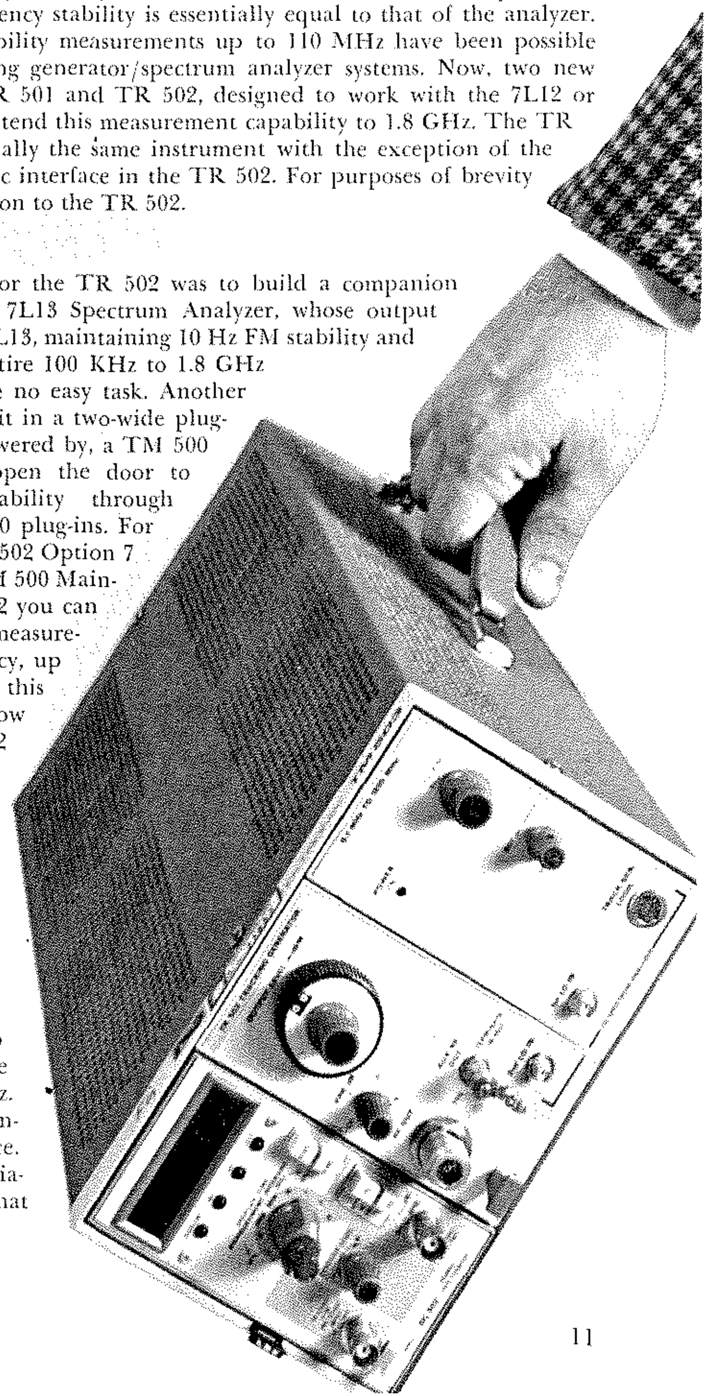
A high-stability 100 KHz to 1.8 GHz tracking generator

Tracking generators, working with spectrum analyzers, offer significant advantages over other frequency-response measurement techniques. A continuous, well-defiined display, freedom from distortion, wide dynamic range, and operating ease are all benefits derived from using a tracking generator/spectrum analyzer system.

These advantages arise from the fact that the tracking generator's output frequency is synthesized from the spectrum analyzer's local oscillators. The tracking generator's output frequency is always the same as the instantaneous frequency of the analyzer, and the frequency stability is essentially equal to that of the analyzer.

High-resolution, high-stability measurements up to 110 MHz have been possible for some time using tracking generator/spectrum analyzer systems. Now, two new tracking generators, the TR 501 and TR 502, designed to work with the 7L12 or 7L13 Spectrum Analyzer, extend this measurement capability to 1.8 GHz. The TR 501 and TR 502 are essentially the same instrument with the exception of the output attenuators and logic interface in the TR 502. For purposes of brevity we will confine this discussion to the TR 502.



Design goals

The primary design goal for the TR 502 was to build a companion tracking generator for the 7L13 Spectrum Analyzer, whose output would faithfully track the 7L13, maintaining 10 Hz FM stability and display flatness over the entire 100 KHz to 1.8 GHz range. This promised to be no easy task. Another goal was to package the unit in a two-wide plug-in to be housed in, and powered by, a TM 500 Mainframe. This would open the door to added measurement capability through working with other TM 500 plug-ins. For example, by plugging a DC 502 Option 7 Digital Counter into the TM 500 Mainframe powering the TR 502 you can make selective frequency measurements, with counter accuracy, up to 550 MHz. We'll discuss this in greater detail later. Now let's look at how the TR 502 works.

Theory of operation

The spectrum analyzer (7L12, 7L13) up-converts its input signal frequency to a 1st IF of 2.095 GHz by mixing with the 1st LO (local oscillator). It then down-converts the 2.095 GHz to an IF of 105 MHz by mixing it with the 2nd LO frequency of 2.2 GHz.

The TR 502 Tracking Generator reverses this sequence. Referring to the block diagram in Figure 2 we see that

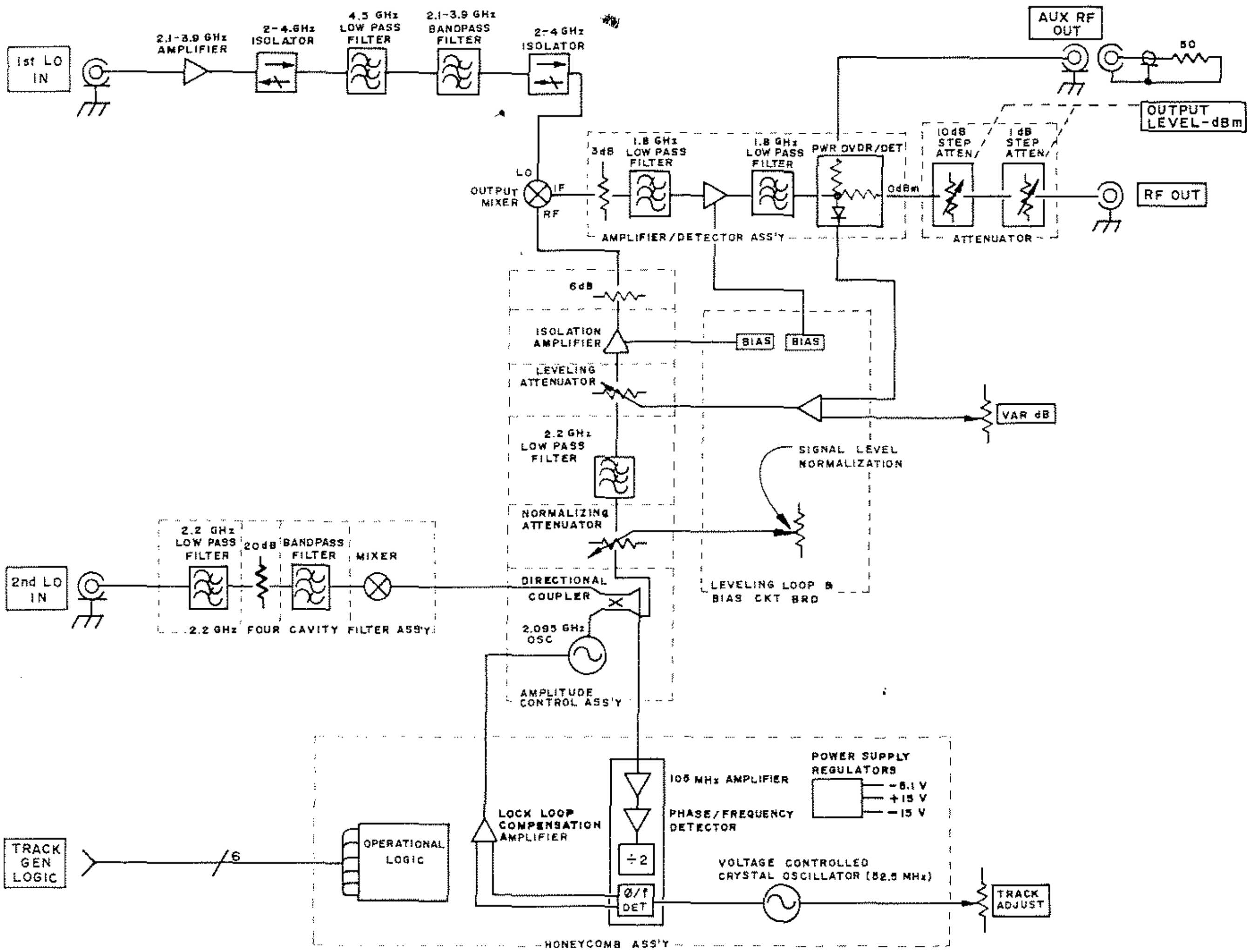


Fig. 1. Block diagram of the TR 502 Tracking Generator.

the 1st LO and 2nd LO from the spectrum analyzer are fed into the TR 502. A voltage controlled oscillator running at 2.095 GHz is mixed with the 2nd LO input of 2.2 GHz. The resultant 105 MHz difference frequency is used in a phase lock loop to keep the 2.095 GHz oscillator in step with the 2nd LO.

The 1st LO input signal ranges from 2.1 to 3.9 GHz and may be either a constant or swept frequency depending on the operating mode of the spectrum analyzer. The 1st LO signal is mixed with the 2.095 GHz signal, with the resultant lower difference frequency becoming the output signal frequency of the tracking generator. The output signal is filtered, amplified, automatically leveled, and applied through a step attenuator to the output connector of the tracking generator. Now let's look at the block diagram in greater detail.

The 1st LO signal

The input signal from the spectrum analyzer 1st LO is amplified to a level of about 6 mW by the 2.1 GHz to 3.9 GHz limiting amplifier. From the limiting amplifier the signal passes through a series of isolators and filters to the output mixer. The LO signal level at the output mixer is about 5 mW.

Several different types of filters are used in the TR 502, each chosen for its particular characteristics. The 4.5 GHz low-pass filter is a tubular type, while the 2.1 to 3.9 GHz bandpass filter is a 16-element interdigital filter. An interesting side-point is that in manufacturing the interdigital filter, combined tolerances are held to less than 0.001 inch to eliminate the need for tuning the filter.

The role of the 2nd LO

Turning to the 2nd LO input, we see that the signal passes through a 20 dB attenuator, to a 2.2 GHz low-pass filter, and thence to a two-diode balanced mixer. All of which are housed in the four-cavity bandpass filter assembly pictured in Fig. 2.

The 2.2 GHz signal is mixed with the 2.095 GHz oscillator signal to generate the 105 MHz signal used to phase lock the 2.095 GHz oscillator. The 105 MHz signal is divided by two and compared to a 52.5 MHz crystal-controlled oscillator to develop the compensating phase lock signal.

The 2.095 GHz oscillator uses a resonant micro-strip line in the collector of a common-base transistor oscillator to establish its frequency. It is tuned over a range of about 20 MHz by varying the collector voltage to change the collector-to-base capacitance.

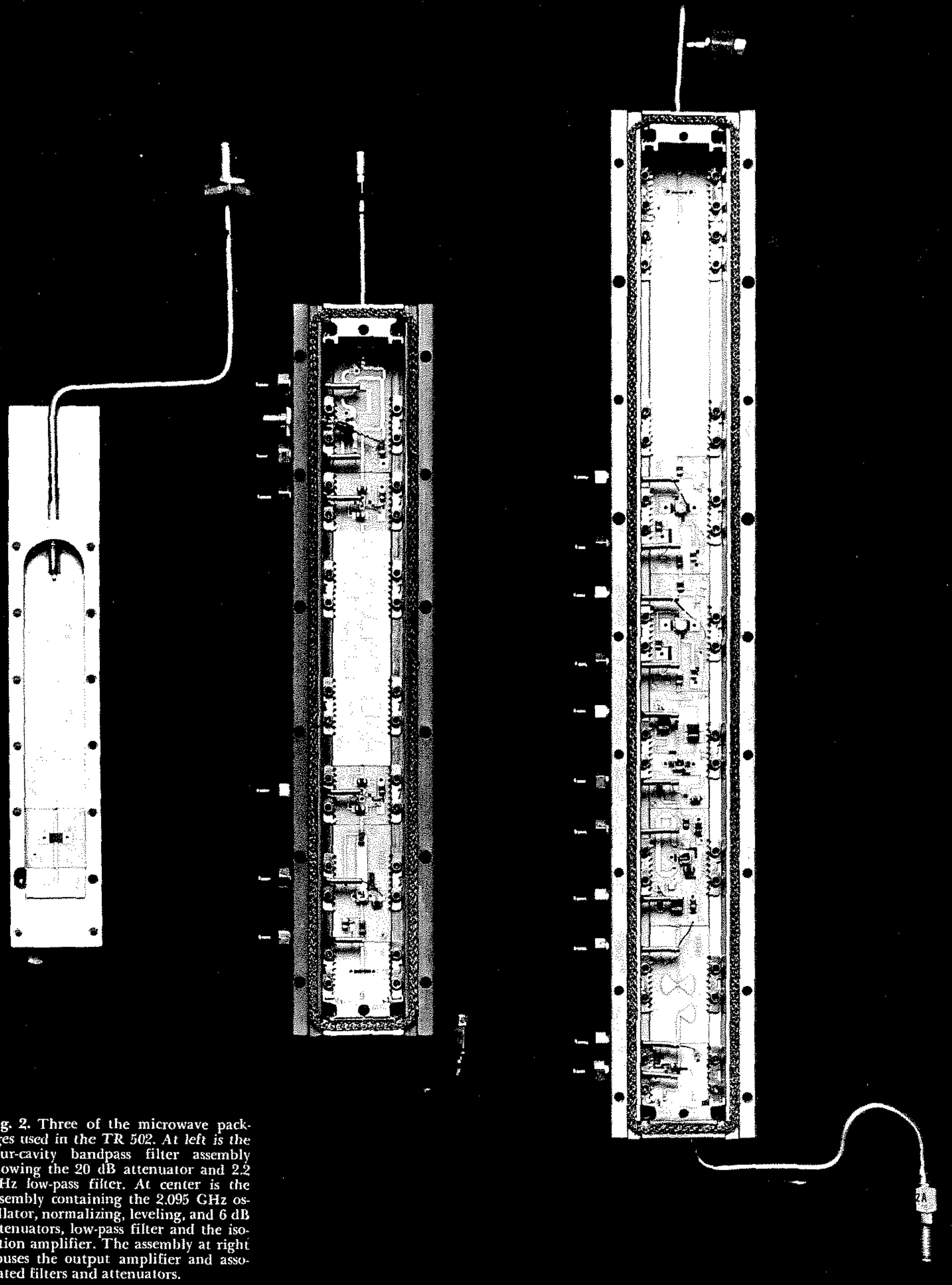


Fig. 2. Three of the microwave packages used in the TR 502. At left is the four-cavity bandpass filter assembly showing the 20 dB attenuator and 2.2 GHz low-pass filter. At center is the assembly containing the 2.095 GHz oscillator, normalizing, leveling, and 6 dB attenuators, low-pass filter and the isolation amplifier. The assembly at right houses the output amplifier and associated filters and attenuators.

The 2.095 GHz signal passes through a directional coupler to a PIN-diode attenuator where initial adjustment of the output level range is made. The signal then passes through a 2.2 GHz low pass filter to a second PIN-diode attenuator, where automatic leveling of the TR 502 output signal occurs. Since the IF amplitude level out of the mixer tracks the rf signal level (with about 6 to 8 dB of loss), we control output signal amplitude by controlling the rf signal level into the mixer. From the leveling attenuator, the rf signal passes through an isolation amplifier providing about 7 dB of gain and greater than 20 dB of reverse isolation. Its output drives the output mixer through a 6 dB attenuator.

The 2.095 GHz oscillator, normalizing, leveling, and 6 dB attenuators, the low-pass filter, and isolation amplifier are constructed in a comprehensive hybrid and microwave package (dubbed CHAMP by the project engineers). This type of construction offers tremendous flexibility and economy compared to earlier techniques.

The output amplifier

The output amplifier section also uses the same type of construction (See Fig. 2). The lower conversion frequencies from the output mixer pass through a 3 dB attenuator and 1.8 GHz low-pass filter to the wideband amplifier. The 3 dB attenuator provides a wideband termination for the mixer. The 1.8 GHz low-pass filter is an elliptic function filter, flat to 1.8 GHz and rolling off with a sharp notch at 2.095 GHz. The 0 to 1.8 GHz signal is amplified by about 40 dB by the four-stage wideband amplifier, then passes through another 1.8 GHz low-pass filter to the power divider and level detector. Each stage of the output amplifier is supplied by a separate bias supply. The bias circuits and amplifiers are connected as a feedback loop with the collector load current of the amplifier sensed by the input resistor to the operational amplifier. This voltage is compared to a +10V reference. The operational amplifier output drives the base of the rf amplifier to set the bias, holding the collector voltage constant at +10 volts. The 1.8 GHz low-pass filter following the amplifier attenuates frequencies above 1.8 GHz which may be generated by the amplifier.

The level detector is a directional peak detector that senses the forward power but not the reflected or reverse power. Forward power is independent of the load. The output attenuator provides calibrated 1 and 10 dB steps of output power over the range of 0 dBm to −59 dBm, with a variable control adding up to 2 dB of attenuation between steps. The output amplitude is flat within ±0.5 dB from 100 KHz to 1.8 GHz. The TR 502/7L13 system is flat within ± 2dB over the same frequency range.

Operational innovations

We mentioned earlier that the TR 502 could be used with the DC 502 Option 7 Digital Counter for making accurate frequency measurements. Through an innovative technique, using dual rf outputs, frequency can be measured accurately at spectrum analyzer sensitivities. The theory of this powerful convenience is very simple. The sweep generator in the analyzer stops at mid-screen, and a command is sent through the tracking generator to the counter to count. When counting is completed (in 10 or 100 ms), the counter commands the analyzer to continue the sweep. The user sees the momentary pause as a bright dot at mid-screen. The count time, and hence the resolution of the measurement, is determined by the phase lock mode of the analyzer.

When the analyzer is operated in manual, external sweep, or a non-sweep mode, the counter will count continuously. The DOT INTENSITY control on the TR 502 enables the logic circuitry for counter measurements and sets the dot intensity on the analyzer display.

Mechanical innovations

The bulk of the rf circuitry is housed in the left-hand portion of the plug-in. We have already mentioned the comprehensive hybrid and microwave package used for the 2.095 GHz oscillator and associated signal path components, and the 0 to 1.8 GHz amplifier. Pretesting of the individual substrates in these units saves considerable final test time and substantially reduces the likelihood of encountering a defective unit in final test. The cost of repairing these units is also minimal since a failure does not necessitate replacing the entire unit. The defective substrate can be quickly isolated and replaced at a fraction of the cost of the entire assembly. The right hand half of the plug-in contains a 6-compartment honeycomb casting that houses the 105 MHz amplifier, 52.5 MHz oscillator, the ø/f detector, and the bias and leveling circuits. Excellent shielding, good rf environment, ruggedness, and good serviceability are provided by the honeycomb structure.

Summary

The TR502/7L13 Tracking Generator, Spectrum Analyzer system provides highly accurate frequency response measurements over the range of 100 KHz to 1.8 GHz with resolution to 30 Hz. This narrow bandwidth resolution yields a wide dynamic range (> 110dB) permitting measurements well down on the skirts of device responses. The system can be used with the DC 502 Option 7 Digital Counter to select and accurately determine frequencies up to 500 MHz. As a CW source, the TR 502/ 7L13 offers a stability of 10 Hz when the analyzer is in a zero-span (non-sweep) mode.

Acknowledgements

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For complete specifications on the TR 502 we invite you to return the inquiry card accompanying this issue of Tekscope.