Satellite Finder Meters: Modification and Characterisation

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Abstract – ***In the range of accessories available for TVRO satellite equipment are various implementations of a 'satellite finder'. These range from simple, relatively inexpensive, analogue designs to complex and more expensive digital designs. No attempt is made to describe the whole range available and this is left to the reader to research. This note describes how one model of the simple analogue type can be re-purposed to provide a radio frequency (RF) to DC voltage detector suitable for use in a total power telescope. Details will be given of a means to power the satellite finder without the presence of a satellite receiver. Some rough characterisation of a particular satellite finder meter is done.***

I. INTRODUCTION

An excellent pathway into amateur radio astronomy is via re-purposing TVRO satellite equipment. Arguably the most suitable type of TVRO gear is that which is used for Ku-band (near 12 GHz) reception. Use of this gear, originally designed to receive TV signals from geosynchronous satellites, is convenient as the dishes are small and can be easily handled. A simple system can easily be assembled which can demonstrate black-body microwave radiation from a number of sources, such as the Sun, the ground, buildings, trees and humans. With careful operation it might be possible to detect the Moon with this equipment. Offset[1] dish sizes typically start from around 18″ (46 cm) to 34″ (85 cm) . Although less common, sizes of 40″ (100 cm) and higher are also available. The author currently possesses two offset dishes of dimensions 75 cm by 65 cm. These elliptical dishes have the widest dimension in the vertical plane.

Apart from the mounting configuration for the dish, the only extra TVRO gear required to assemble a simple microwave radio telescope is a satellite finder meter and an LNBF. Basic modification and characterisation of such a satellite finder meter will be described, as well extra modifications which can be done to implement a simple data logging interface.

II. SATELLITE FINDER METER USED

Not only is there a large range of satellite finder meters, but just within the subset of cheap analogue satellite meters there is a significant number of models. However, the two examples in the author's possession (as shown in Figure 1 and Figure 2) appear to be essentially based on the same circuit, albeit with slightly different printed circuit board (PCB) layouts and component population levels.

The undesignated model on the right in Figure 1 has LED indicators for vertical and horizontal polarisations settings and the presence or otherwise of the local oscillator 22 kHz control tone. The model on the left (SF-95) has the circuitry traces and pads on the PCB for the LED indicators, but the components are not loaded. The absence of these components provides the opportunity to utilise the unused pads as anchor points for some of the external connections.

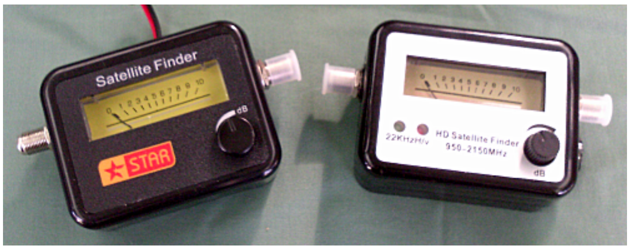

Figure 1: Sample Satellite Finder Models (SF-95 on left)

Examination of Figure 2 shows that the two different models have similar circuits and PCB layouts.

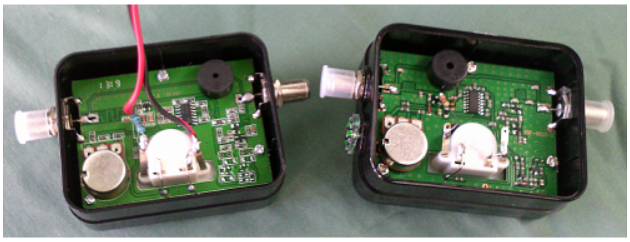

Figure 2: PCB Layout for the Sample Satellite Finders (SF-95 on left)

III. MODIFICATION FOR EXTERNAL POWER SUPPLY

Figure 3 gives a close-up view of the SF-95 model PCB showing where the wires are connected for the basic modification of providing an external power supply which obviates the need for a satellite receiver.

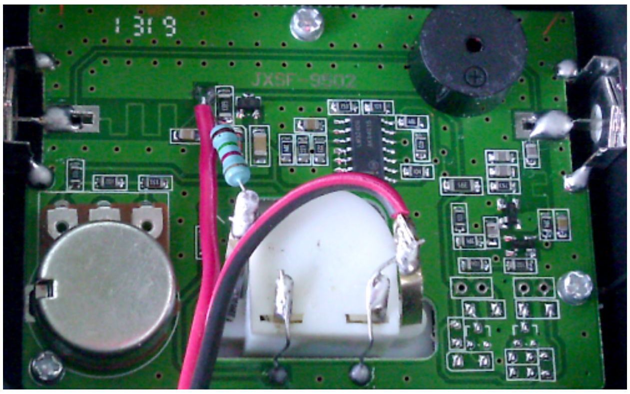

Figure 3: Close-up of the SF-95 Satellite Finder PCB

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[1] Offset dishes move the focus point off to one side so that an LNBF placed there does not obstruct the view of the signal source being received.

Normally the 10V to 19V power (from a satellite receiver) comes in on the left-hand F-connector and passes straight through, via the track loop at the upper section of the PCB, out the right-hand F-connector and so on to power the LNBF. In this normal operation the signal finder electronics taps off its power through the printed inductor (the square-wave shaped track connected to the left-hand F-connector) which presents an impedance to the 1 Ghz RF signal passing down from the LNBF on its way to the satellite receiver. To further filter out the 1 GHz RF energy, a small chip capacitor (value unknown) bypasses the right-hand side of the inductor. It is from this point that the finder electronics takes it power supply. In this model an 8 V zener diode is used to regulate the voltage to the finder electronics.

In the modification, for mechanical strength reasons, the positive side of the external power supply (nominally 12 V) is connected to the 'north' end of the 1K5 voltage dropping resistor which supplies the meter lamp. That end of the resistor is connected to the positive power supply rail of the finder's electronics. The negative side of the external power supply is connected to the earth side of the meter. Both meter movement and meter lamp negatives are connected together on the right-side of the meter in rear view.

This added connection not only powers the finder electronics, but feeds back out through the printed inductor, on through the bridging track loop and out the right-hand F-connector to power the LNBF.

IV. MODIFICATIONS FOR EXTERNAL DATA LOGGING

The satellite finder meter is a wideband RF detector which normally is used to align a dish on a geosynchronous satellite. The bandwidth is ostensibly from 950 MHz to 2150 MHz, the frequency range of the IF output of an LNBF. In the models shown here the DC output of the detector, after amplification, is used to drive a signal level analogue meter. Some variations of the basic finder are designed to drive an LED level display – but the author, being of a certain 'vintage', prefers the mechanical meter display type. Although the wideband nature of the finders is a limitation for TVRO satellite setup (as it cannot discriminate between various channels within the transmission band of a satellite), for radio astronomy the wideband nature of the detector is an advantage, improving sensitivity - assuming, of course, those same satellites in the Clarke Belt do not end up in the beamwidth of the receiving dish.

In the satellite finder the output of the operational amplifier which drives the meter is connected through a series resistor to the positive meter movement input terminal. The DC voltage which drives the meter can be tapped off for logging purposes. It is important in the tapping process to avoid connecting directly across the meter as at that point the signal is a current drive and the impressed voltage is affected by the characteristics of the meter. Also the e.m.f. generated by mechanical vibration (microphonics) could introduce errors, although the author considers that these effects would be insignificant – but nevertheless should be avoided as a matter of good practice.

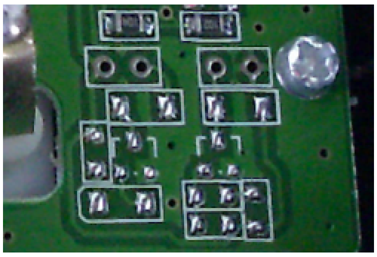

Figure 4: Unused Area of SF-95 PCB

The correct point to tap off the DC voltage is the relatively low-impedance output of the driving operational amplifier.

The unused part of the PCB of the SF-95 satellite finder as shown in Figure 4 can be conveniently utilised for mounting a simple interface between the op-amp output and external equipment. Connecting to the op-amp output (pin 7 – LM324) through a separate, added, series resistor provides both a measure of protection from external transients and also forms part of a simple low-pass filter (LPF).

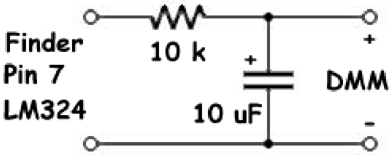

Figure 5: Simple Low-Pass Filter

The value of the series resistor is influenced by the impedance of the external circuitry – for the high impedance input of a DMM a series resistor of the order of 10 k will not have a significant effect. A shunt capacitance of about 10 uF will provide a useful level of low-pass filtering.

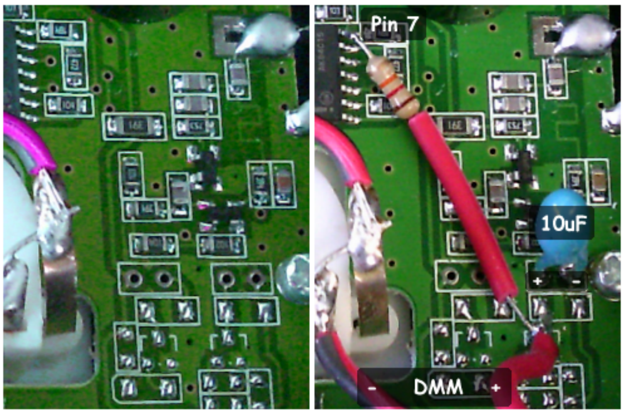

Figure 6: Before and After Modification - DMM Interface LPF

Note that although the circuit in Figure 5 shows a 10 k resistor, Figure 6 reveals that a 12 k value was used. Basically this value is not critical and the author's component stock had no loose 10 k resistors, but plenty of 12 k items.

V. FINDER CHARACTERISATION

Although the satellite finder meter is by no means a high-quality instrument, it is useful to at least perform a rough characterisation exercise. Once again, the SF-95 model is used.

Figure 7: Test Setup

NOTE: Be aware that the signal input (LNBF side) has the DC power supply voltage applied to the centre conductor. To protect the test gear, a series blocking capacitor (see Figure 8) is inserted between the finder and the signal generator.

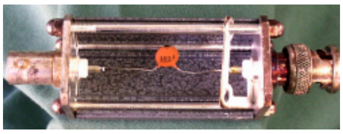

Figure 8: Series Blocking Capacitor - 100 pF

The SF-95 has a level control on the front which, in normal operation, is used to adjust the deflection of the meter as the task of alignment of the dish to a satellite signal progresses. Tracing out the circuit visually and with the aid of a continuity meter indicates that the circuitry involved with the front panel control implements an offset function – rather than a gain control.

Reference to the partial circuit traced out as shown in Figure 9, reveals that the DC signal from the RF detector circuitry is amplified by a fixed gain ≈ 39 after being compared against an offset voltage set by the front panel control potentiometer. The value of the potentiometer is not known as it is unmarked and would require isolation from the circuit to measure.

The nominal input frequency range of the satellite finder is 950 MHz to 2150 MHz which matches the down-converted signal frequency range of the TVRO LNBFs. The author does not have a signal source for that frequency range, but has a signal generator with a range of 10 kHz to 520 MHz, so a test signal of 520 MHz is used. Although the test frequency is not in the design range, because the characterisation does not involve determining a frequency response, but instead the relationship between RF input level and detector output voltage, this is not a problem.

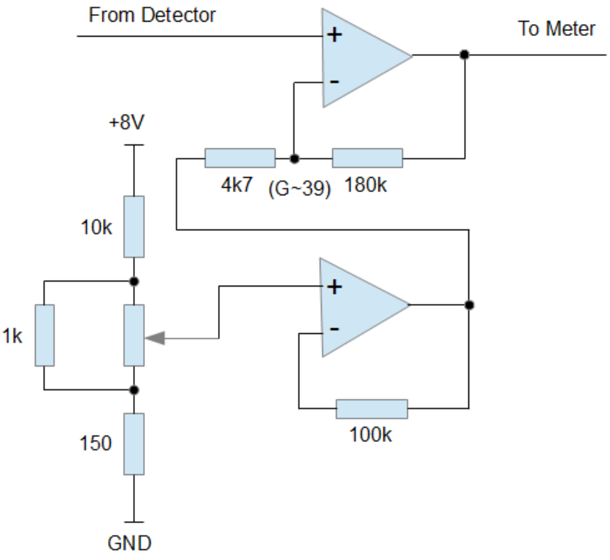

Figure 9: Satellite Finder SF-95 Partial Circuitry

Measurements were taken on the modified SF-95 by noting the output voltage versus RF input level and plotted as shown in Figure 10 and Figure 11.

The RF input level was varied from 0 dBm to -20 dBm. The frequency was fixed at 520 MHz.

Four test conditions were set up, where the front panel level control was adjusted according the criteria listed below. Then the signal generator was connected and measurements made and recorded.

1. With no signal applied, the front panel level control is set such that the DC output voltage is ≈200 mV.
2. With no signal applied, the front panel level control is set such that the DC output voltage is ≈10 mV.
3. With the LNBF connected and the dish pointed at the ground (≈300 K°), the front panel level control is adjusted such the finder meter needle is on the '10' mark (FSD).
4. With the LNBF connected and the dish pointed at the ground (≈300 K°), the front panel level control is adjusted such the finder meter needle is on the '5' mark (FSD).

The graph in Figure 10 plots ***linear*** volts against dBm and indicates that Test Conditions #1 and #2 are the most suitable. Test Conditions #3 and #4 show a smaller dynamic range due to saturation and noise limitations respectively.

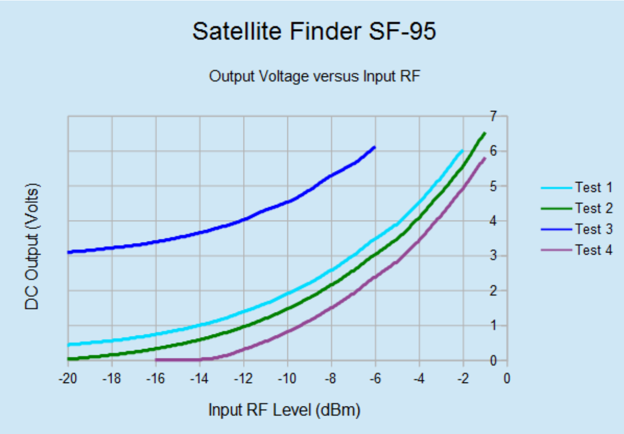

Figure 10: Modified SF-95 Linear Output Voltage versus Input RF dBm

Changing the voltage axis to a logarithmic scale as shown in Figure 11 reveals that Test Condition #1 alone produces a straight line over a usable range of input RF level for this log-log plot. Accordingly, it is this condition which is most useful, as the logarithm of the output voltage is directly proportional to the logarithm of the power input where...

$$\log(\frac{V_2}{V_1})=0.643*\log(\frac{P_2}{P_1})$$

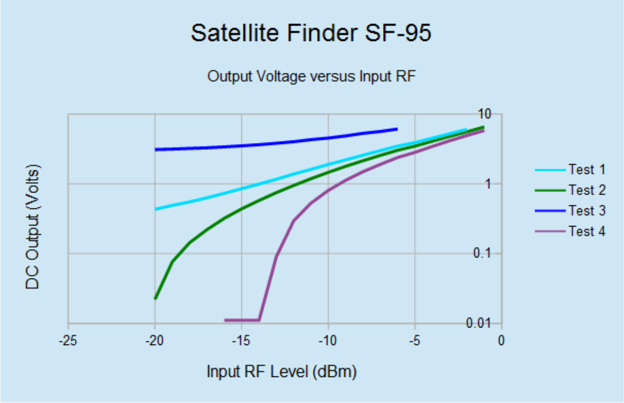

Figure 11: Modified SF-95 Log Output Voltage versus Input RF dBm

As a result, the recommended process of setting the front panel control is to point the dish a cold patch of sky and adjust the satellite finder front panel level control such that the DC output measures ≈200 mV. This should place the finder at a setting which makes as much as possible use of the output voltage range while preserving the direct relationship between input power and output voltage. Note that this direct relationship refers only to the output voltage as measured by a DMM – not the finder's meter deflection, which follows a different relationship.

To finish off the measurements a field check on some typical targets was done. This check showed, after setting the output voltage to ≈220 mV on a cold patch of sky, a reading of 2.48 V pointing at the ground and 2.97 V on the Sun.

The reading on the Sun was higher than expected. It was expected to be less, not greater, than the ground-pointing reading (≈300 K°) judging by the results given by other parties with similar 'Itty Bitty Telescope'-type (IBT) setups . However, it is noted that the dish size used by the author is larger than those usually found in those other examples. Therefore, the 0.5° angle subtended by the Sun fills a larger proportion of the narrower beamwidth of the author's larger dish compared to the smaller dishes. Consequently, the average temperature over the beamwidth would be higher than for the smaller dishes.

VI. 'SANITY' MODIFICATION

In addition to the analogue meter output display there is an audible indication of level. This provided by a basic voltage to frequency converter circuit (an RC oscillator using an op-amp from the LM324) which drives a miniature piezoelectric speaker. These speakers are the black round button-like objects seen in Figure 2 and Figure 3. As the needle of the signal meter increases, the frequency of the sound (perhaps more accurately described as the 'screech') increases. The utility of this is limited, in the author's opinion, as it doesn't start screeching until the needle reaches the '2' mark and seems not to be a smooth progression up the scale. Although tapping off the drive to the piezoelectric speaker is a simple way of getting data into a soundcard interface for data logging purposes, the dead-band at the lower end of the scale is a nuisance. If the author was to implement this method (voltage to frequency conversion) use, instead, would be made of a special-purpose integrated circuit.

Consequently, for the case discussed here (the DC voltage is output for data logging) what is left is an annoying sound which cannot be muted and has no volume control. The author intends to use the finder for long-term drift scan data logging. Under these circumstances the 'novelty' of the audible indication will surely wear off in short order – not to mention the effect on other parties in earshot who do not have radio astronomy as a hobby.

Two methods of 'muting' the sound come to mind. As all modifications so far have not needed the cutting of PCB tracks or removal of components, finding a simple method for this modification appeals.

It occurred to the author that a simple, albeit brutish, method of silencing the speaker would be to squeeze hot glue through the hole on top of the speaker, filling the speaker cavity within. This would certainly gum the speaker up and kill the sound. However, this is definitely a permanent solution and there is a concern that the mechanical loading of the piezoelectric element would make it appears to be a much lower impedance load for the op-amp. This, assuming the oscillator didn't stall, might increase the op-amp's dissipation.

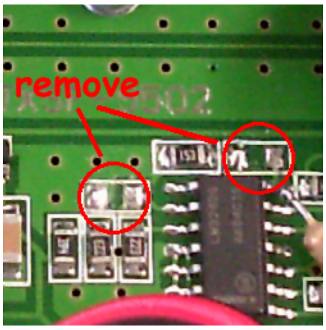

Figure 12: Remove Circled Components to Silence Audible Tone

The other method involves stopping the signal level voltage drive to the RC oscillator by removing one chip resistor (the right-most component in Figure 12) and, for good measure, removing the chip capacitor from the oscillator (the left-most component in Figure 12). This has the advantage of not being permanent and is the method adopted.

Note that the author does not have any SMT de-soldering tools and resorted to the 'agricultural' method of carefully cutting the components in two with a pair of fine side-cutters and then removing each half with a standard soldering iron.

VII. CONCLUSION

A satellite finder meter (SF-95) has been modified to be powered by an external 12 V supply. The DC output voltage of the finder's RF detector has been brought out through a simple LPF suitable for reading by a DMM.

Figure 13: Completed, Modified SF-95 Satellite Finder Meter

The audible indication function has been disabled to make the finder 'user friendly' for long observations.

While the modification detail shown is for an SF-95 model finder, other models of this type will likely have the same basic circuitry and so the information here could possibly be applied to those units.

Some basic characterisation was done. It should be noted that measurements were only done on a single unit – variation across units (or different models) is unknown.

The SF-95 finder, thus modified, is suitable for simple total power observations on strong signals, such as the Sun, ground, trees, humans and, possibly, the Moon.