SAW STABILIZED RADIOSONDES*

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ABSTRACT

Two SAW stabilized oscillators with FM and PAM capability have recently been designed and breadboarded to provide 300 ppm frequency stability over a -70°C to +70°C environment. The circuits are being developed for use in low cost, expendable radiosondes operating at 403 MHz and 1680 MHz.

Introduction

By the late 1980s the design of radiosondes used by the US Army must be significantly improved both to increase frequency stability and to incorporate frequency modulation. The current design uses a free-running, amplitude-modulated, transistor oscillator. The instability of the oscillator limits the number of sondes which can be used in a given area without interference. It is expected that future applications will require 300 ppm frequency stability over a -70°C to +70°C environment. In addition, the circuits will be required to transmit 0.5W over the 1660-1700 MHz band, and be capable of both pulse amplitude modulation and frequency modulation. For some European countries, the radiosondes need to be redesigned to operate in the 400-406 MHz band, transmitting 200 mW. TRW has completed the design of the 1680 MHz breadboard oscillator and the design of the 403 MHz oscillator is near completion. The required performance for these circuits is summarized in Table 1.

Table 1. OSCILLATOR REQUIREMENTS

Frequency	1660-1700 MHz	400-406 MHz
Settability	200 ppm (±168 KHz)	100 ppm (±20 KHz)
Stability	<300 ppm	<300 ppm
Output Power	500 mW	200 mW
Modulation	PAM (DC to 2000 pps) FM (100 KHz, >300 KHz/V)	PAM (DC to 2000 pps) FM (100 KHz, >300 KHz/V)
Temperature	-70°C to +70°C	-70°C to +70°C

Since the circuits will be used in an expendable radiosonde, cost, size, weight, and power are important design considerations.

An attractive approach to these circuit requirements is a SAW stabilized oscillator. Surface acoustic wave delay lines can provide excellent uncompensated temperature stability, excellent phase noise, and their use greatly reduces circuit complexity (as compared to a crystal oscillator-multiplier chain). Whereas unstabilized microwave oscillators can be expected to have temperature stabilities between 100 ppm/°C and 1000 ppm/°C, SAW stabilized oscillators can achieve stabilities 2 to 3 orders of magnitude better than this unstabilized performance. SAWs yield this improved performance due to their high Q, Q here referring specifically to their large phase slope or delay.

The requirements for stability, moderate tuning bandwidth, and FM complicate the oscillator design. Stability is enhanced by increased phase slope - with the resulting narrow bandwidth delay lines. Tuning and frequency modulation are enhanced by reducing phase slope. A compromise between these requirements has been made through the use of multiple SAW delay lines for the 1680 MHz circuit, and temperature compensation for both circuits.

Description of 1680 MHz Oscillator

A block diagram of the 1680 MHz oscillator (Ref. 1) design is shown in Figure 1. The SAW oscillator

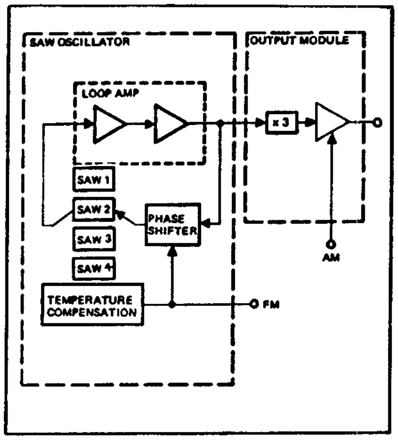

Figure 1. 1680 MHz OSCILLATOR BLOCK DIAGRAM

output frequency is at one-third the desired radiosonde transmission frequency. The output module consists of circuitry which both frequency multiplies (X3) and amplifies the SAW oscillator output. The SAW oscillator consists of four selectable delay lines, each covering a quarter of the 553.3-566.7 MHz band, a quadrature hybrid phase shifter, and loop amplifier. The loop oscillates over the 553.3 to 566.7 MHz band, providing approximately +12 dBm output power. The oscillator frequency is adjustable through a potentiometer and can be modulated electronically. The output module consists of a X3 transistor multiplier and power amplifier.

Measured performance of the 1680 MHz oscillator breadboard is shown in Figures 2 and 3. Output power vs frequency is plotted in Figure 2. Note that a minimum of +26.8 dBm (480 mW) was achieved.

Figure 3 shows plots of the frequency stability vs temperature for each channel. This stability is the combined effects of the SAW parabolic characteristic, phase shifter drift, and sensistor compensation. Table 2 summarizes performance of the circuit. Finally, Table 3 shows a comparison of the performance of the existing oscillator and circuits discussed here. Figures 4 and 5 show photographs of the brassboard oscillator.

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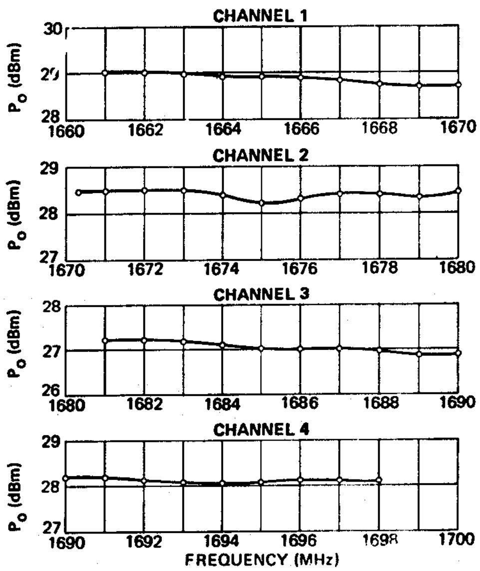

Figure 2. OUTPUT POWER vs FREQUENCY

Table 2. PERFORMANCE SUMMARY

TEMPERATURE STABILITY/P_{OUT}			
CHANNEL	CENTER FREQUENCY (MHz)	P_{OUT} (dBm) MIN.	Δf (ppm)
1	1665.0	+28.70	242
2	1675.0	+28.20	257
3	1685.0	+26.80	214
4	1695.0	+28.00	222

SPURIOUS LEVEL FREQUENCY (MHz)	ORIGIN	P_{OUT} (dBm)	(dBm)
555.0	SAW FREQUENCY	-25.5	54.5
1110.0	2X SAW FREQUENCY	-25.5	54.5
3330.0	2X F_{OUT}	+ 9.5	19.5
5071.0	3X F_{OUT}	-28.0	57.0

FREQUENCY PULLING
ΔF = 286 KHz (± 143 MHz)

AM (V_{IN} = 1.414V)
P_{ON} = +28.9 dBm
P_{OFF} = -10.0 dBm

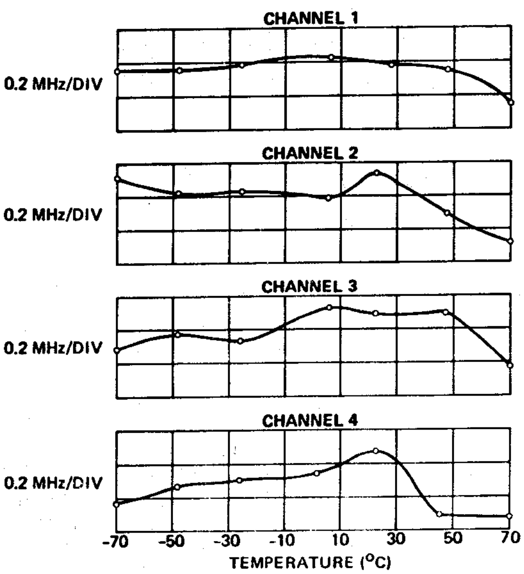

Figure 3. FREQUENCY STABILITY vs TEMPERATURE

Table 3. PERFORMANCE COMPARISON

OSCILLATOR	FREQUENCY STABILITY: TEMPERATURE -70 °C TO +70 °C	FREQUENCY STABILITY: OTHER (ELECTRONICS, ETC.)	FREQUENCY SETTABILITY	TOTAL BANDWIDTH
PRESENT L.C. OSCILLATOR	1500 ppm		100 ppm	1600 ppm
	2.52 MHz		168 KHz (±84 KHz)	2.69 MHz
PROJECTED CAPABILITIES (CONTRACT REQUIREMENTS)	300 ppm		200 ppm	500 ppm
	160 ppm	140 ppm	336 KHz	840 Hz
	269 KHz	235 KHz	(±168 KHz)	
ACHIEVED PERFORMANCE	260 ppm		40 ppm	300 ppm
	160 ppm	100 ppm	67 KHz (±33.5 KHz)	504 KHz
	269 KHz	168 KHz		

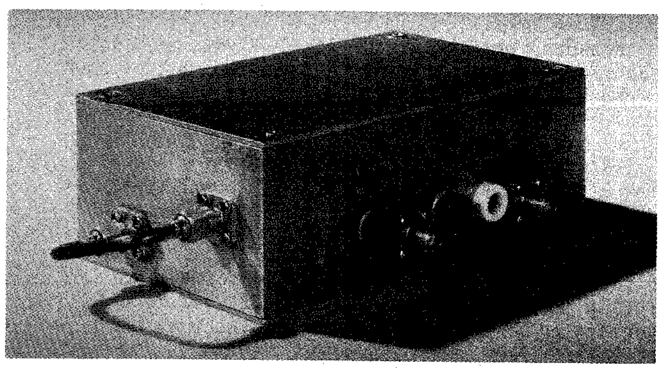

Figure 4. BRASSBOARD RADIOSONDE

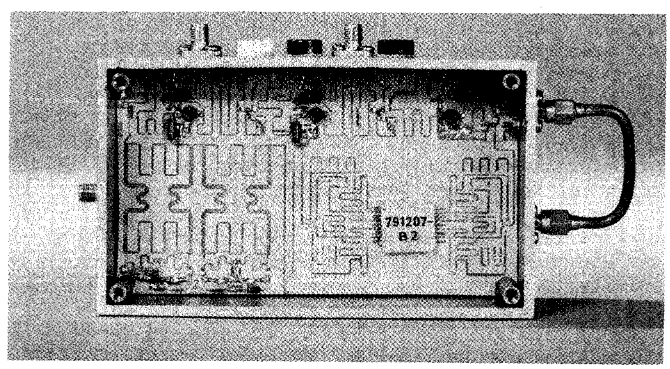

Figure 5. SAW OSCILLATOR MODULE

Description of 403 MHz Oscillator

The design of the 403 MHz oscillator is currently in progress. Its block diagram is basically that shown in Figure 6. In this circuit, a single delay line is used, no frequency multiplier is required, and an injection locked oscillator is used to amplify the SAW oscillator output level.

The measured performance of this circuit is shown in Figures 7 and 8. Note that this preliminary measurement shows the compensation reduced the temperature stability from over 5000 ppm to less than 400 ppm. Slight modification of the compensation circuit should reduce this value to less than 200 ppm. To minimize circuit costs, the SAW delay line was packaged in a TO-5 can. A photo for the delay line is shown in Figure 9.

Conclusion

This work has demonstrated an ideal application for surface acoustic wave devices. Stable microwave frequencies were obtained which far exceeded the stability of currently available radiosondes, both at 1680 MHz and 403 MHz. It is unfortunate that temperature compensation was required to achieve the results. The variation of SAW delay over this temperature range is less than 200 ppm. Temperature compensation was dictated by the requirements for an electronic phase shifter in the loop. Currently, development of both of these circuits is being continued. The next generation of these oscillators will include the incorporation of RF-LSI loop amplifiers packaged with the delay lines in a low cost, hermetic package.

Acknowledgements

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References

[1] D.J. Dodson, K.F. Lau, and M.Y. Huang, "SAW Stabilized 1680 MHz Microwave Oscillator", 34th Annual Frequency Control Symposium Proceedings, May, 1980, pp. 221-227.

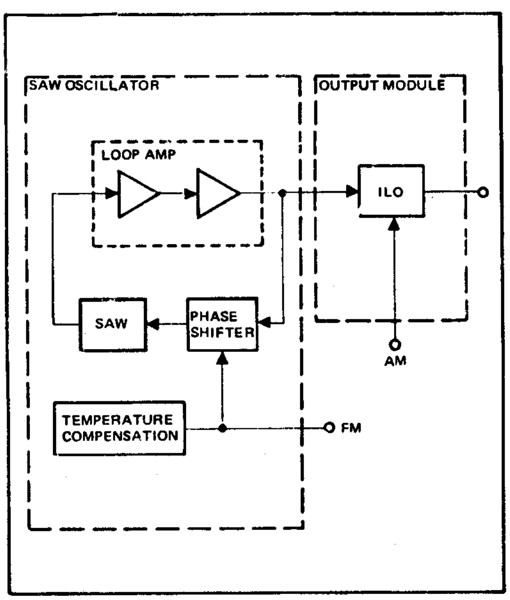

Figure 6. 403 MHz OSCILLATOR BLOCK DIAGRAM

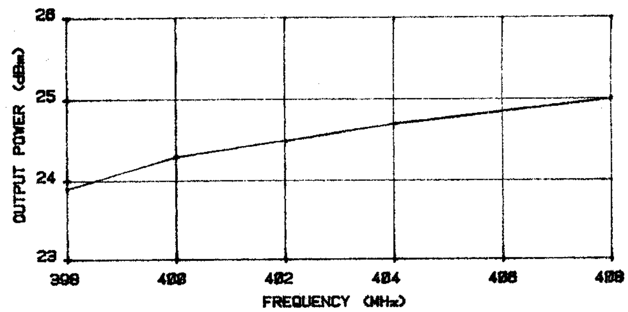

Figure 7. OUTPUT POWER vs FREQUENCY

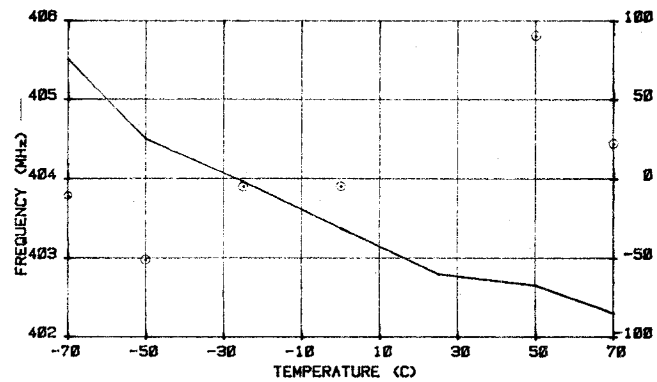

Figure 8. OSCILLATOR TEMPERATURE STABILITY

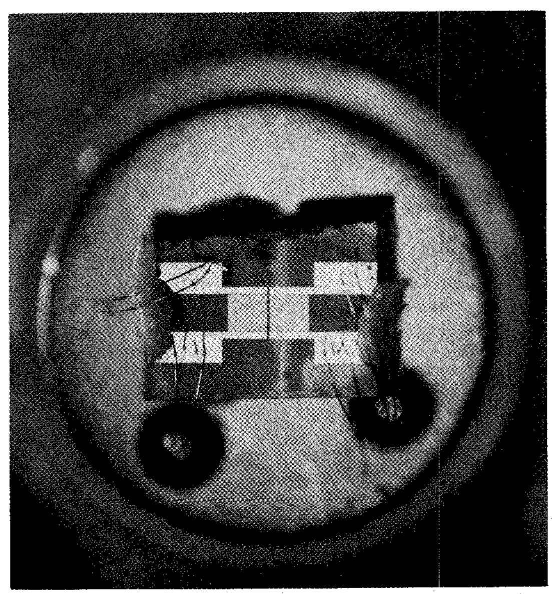

Figure 9. PHOTOGRAPH OF DELAY LINE