TECHNICAL MEMORANDUM (NASA) TM 30

LOW-COST MECHANICAL FILTERS FOR OMEGA RECEIVERS

A set of mechanical filter assemblies has been obtained for possible use in the RF front-end of an OMEGA navigation receiver. The resonators provide very narrow bandwidth performance with good skirt selectivity in a simple two-stage circuit. It is recommended that these filters be used in a complete receiver system for long-term evaluation on reception of low-level OMEGA signals.

by

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(NASA-CR-148767) LOW-COST MECHANICAL FILTERS FOR OMEGA RECEIVERS (Ohio Univ.) 9 p HC $3.50 CSCL 17G

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I INTRODUCTION

A pair of prototype SEIKO low frequency mechanical filters have been obtained for use as the RF front-end components of an OMEGA-VLF navigation receiver. The filter units are of interest because of very narrow bandwidths and high skirt selectivity to minimize noise and off-channel carriers in the reception of OMEGA signals. In addition, the SEIKO filters have a characteristic low impedance of 75 to 5000 ohms which results in less critical PC board circuitry compared to some previous resonators with termination resistances of 25,000 ohms to 5 megohms.

II MECHANICAL FILTERS

Low frequency mechanical filters in the 300 Hz to 80 kHz range have been developed from materials and methods used in manufacturing precision timepieces. Major applications have been in frequency-selective calling devices for paging systems and in telemetering communications equipment. These units are available in a variety of packages with prices in the $20 range. A typical single pole filter assembly for OMEGA (SEIKO model SM-1T) uses a bar type resonator in a compact hermetically-sealed package with a range of specifications as in Figure 1. Recently some lower cost prototype filters, SEIKO model SM-B, have been obtained which have comparable specifications to the SM-1T but are mounted in a molded plastic housing.

III OMEGA VLF RECEIVER FRONT-ENDS

One method of operating an OMEGA receiver is in a tuned RF system where an antenna preamplifier drives a narrowband filter-limiter system. The output of the limiter operates a comparator to generate zero crossings for the OMEGA carrier signals which are further processed with digital hardware or microcomputer phase measuring methods.[1], [2] These TRF methods have the advantage of simplicity in that the front-end components are minimized with the proper choice of filter resonators. Previous receivers have used ceramic or quartz tuning fork resonators. The ceramic filters provide a -3 dB bandwidth of 30 Hz (±15 Hz)[3] and the quartz units a narrower bandwidth of 4 Hz (±2 Hz)[4]. Because the OMEGA format is time multiplexed with a typical station on-time of 1 second, the bandwidth must be wide enough to pass an identifiable signal envelope. In the practical case, a bandwidth of 4 Hz is about as low as can be used. Most existing receivers use an RF front-end filter system with a 30 to 100 Hz bandwidth. However, a narrow bandwidth of 4 to 15 Hz is desirable to further reduce noise and allow some signal reception in borderline cases such as for the Norway A channel on 10.2 kHz which is attenuated by the Greenland ice-cap absorption for many observers in the United States.

IV BANDPASS FILTER CIRCUITRY FOR MECHANICAL FILTERS

A variety of methods can be used in OMEGA TRF systems with a general approach of sequentially reducing the bandwidth from the antenna through a series of bandpass filters until the signal is amplified sufficiently to operate a zero crossing detector. An approach we have found useful is the combination of active bandpass filters with the passive resonators as in Figure 2. This circuit is intended to be driven by an antenna preamplifier[2] with a gain of 20 dB and a Q of 2. The minimum signal plus noise at the input to the resonator filter will be of the order of 100 μv rms with a typical 1 meter E-field whip antenna driving the antenna preamplifier.

The active bandpass filters using the operational amplifiers serve to improve the skirt selectivity and reduce the higher harmonic spurious responses of the mechanical resonators to a negligible level. Other active filter methods involving multiple pole lowpass filter can also be used but the bandpass method has the advantage of simplicity. The active circuitry has good phase stability over a reasonable operating temperature range (5°-50°C) with cermet frequency trimpots and conventional low-cost components. For some applications the tuning capability of the active filters is an advantage in allowing the overall system phase shift to be adjusted for exactly 90° or 180° by stager tuning the stages. The gain and Q of the active gain blocks between each mechanical filter can be adjusted by altering the amplifier feedback resistor from 6.8 k to 15 k ohms for single stage gains of 10 to 20 dB. A total gain of 20 dB is available in the circuit of Figure 2 as shown.

The response of this circuit is illustrated in Figure 3, where the 3 dB bandwidth is about 14 Hz (±7 Hz). Of even greater interest is the excellent skirt selectivity with the adjacent OMEGA channels of 11.333 kHz and 13.6 kHz down -80 dB or greater. The sharp spurious mechanical harmonic responses are illustrated in Figure 4. The active filter stages reduce these to a comfortable -60 dB level or greater. The particular SEIKO SM-B filter units have no upper spurious responses before approximately the 5th harmonic so that virtually any OMEGA channel including the proposed 11.05 kHz frequency can be rejected for a filter tuned to receive the 10.2 kHz channel.

It should be obvious to circuit designers that other multiple pole filter circuit configurations are possible including even narrower bandwidth systems, with more stage complexity within the limitations of passing the time-multiplexed OMEGA sequence for 0.9 to 1.2 second transmission intervals. The circuit of Figure 2 is believed to be adequate for many low-cost OMEGA receiver processing systems.

V OTHER FILTER TECHNIQUES

No direct comparison with ceramic or quartz tuning fork methods are possible other than on the overall system bandwidth. In general, the SM-B mechanical filters require less critical circuitry because of the lower terminating impedance (5 k ohms) compared to 25 k ohms for ceramic filters and 5 megohms for quartz tuning forks. It is possible to achieve a ±2 Hz bandwidth system using a single quartz resonator, but it is much more difficult to achieve a -80 dB skirt selectivity with high Z quartz. Two single pole ceramic filters can provide a ±15 Hz bandwidth with good skirt selectivity but will cost much more than the SM-B mechanical filter units. Thus there are various trade-offs in cost versus performance where the SEIKO mechanical filters are very competitive with other methods.

VI CONCLUSIONS

It is possible to achieve ±7 Hz, -3 dB bandwidth and -80 dB adjacent channel rejection for OMEGA TRF systems in a two-stage filter configuration using prototype SEIKO SM-B mechanical filter units. These filters have the advantage of low-cost ($6 each in 100 piece lots) and low circuit impedance to provide relatively simple PC board assemblies for OMEGA receivers.

VII RECOMMENDATIONS

It is suggested that a complete experimental OMEGA front-end be fabricated using the SM-B resonators and this be evaluated using the Ohio University prototype receiver system in both the MAPLL hardware and the mini-O software processing systems. An extended signal monitoring program should be considered from an electrically quiet location, to determine the possibility of using either the previous STATEK ±2 Hz or the proposed SEIKO ±7 Hz front-end systems for detecting the low-level Norway A channel on 10.2 kHz in Ohio.

VIII ACKNOWLEDGEMENTS

The assistance of Mr. Takashi Abe, Chief Engineer of SEIKO Instruments, Inc., Torrance, California, is gratefully acknowledged in supplying samples of the SEIKO SM-1T and prototype SM-B mechanical filter units. This work was supported in part by NASA Langley Research Center Grant NGR 36-009-017 which is concerned with the development of low-cost VLF navigation methods for the general aviation community. The conclusions and recommendations are those of the author and do not represent an endorsement of a particular product by Ohio University or NASA.

IX REFERENCES

[1] R.W. Lilley, "Binary Processing and Display Concepts for Low-Cost Omega Receivers", J. Institute of Navigation, 22, No. 3, pp. 244-251, Fall 1975.

[2] R.W. Lilley and R.J Salter, "Simulation Analysis of a Microcomputer-Based Low-Cost Omega Navigation System", Proc. Nat. Aero. Symp. Inst. of Navigation, Warminster, Pa., April 28, 1976. Also published as Technical Memorandum (NASA) 26, Avionics Engineering Center, Department of Electrical Engineering, Ohio University, Athens, Ohio 45701.

[3] R.W. Burhans, "Low-Cost, High Performance, VLF Receiver Front-End", Technical Memorandum (NASA) 18, Avionics Engineering Center, Department of Electrical Engineering, Ohio University, Athens, Ohio 45701, September 1975.

[4] R.W. Burhans, "The Mini-O, A Digital Superhet, or a Truly Low-Cost Omega Navigation Receiver", Technical Memorandum (NASA) 20, NASA CR No. CR-144923, Avionics Engineering Center, Department of Electrical Engineering, Ohio University, Athens, Ohio 45701, November 1975.

Center Frequency (kHz)	10.2, 11.333, 13.6
3 dB Bandwidth	min. ±25 Hz
Ripple in Bandwidth	within 1.5 dB
Attenuation	min. 35 dB at ±150 Hz min. 45 dB at ±250 Hz
Insertion Loss	2.5 dB ±2.0 dB
Termination Resistance	5 kohms

Figure 1. Characteristics of SEIKO Type SM-1T Filters.

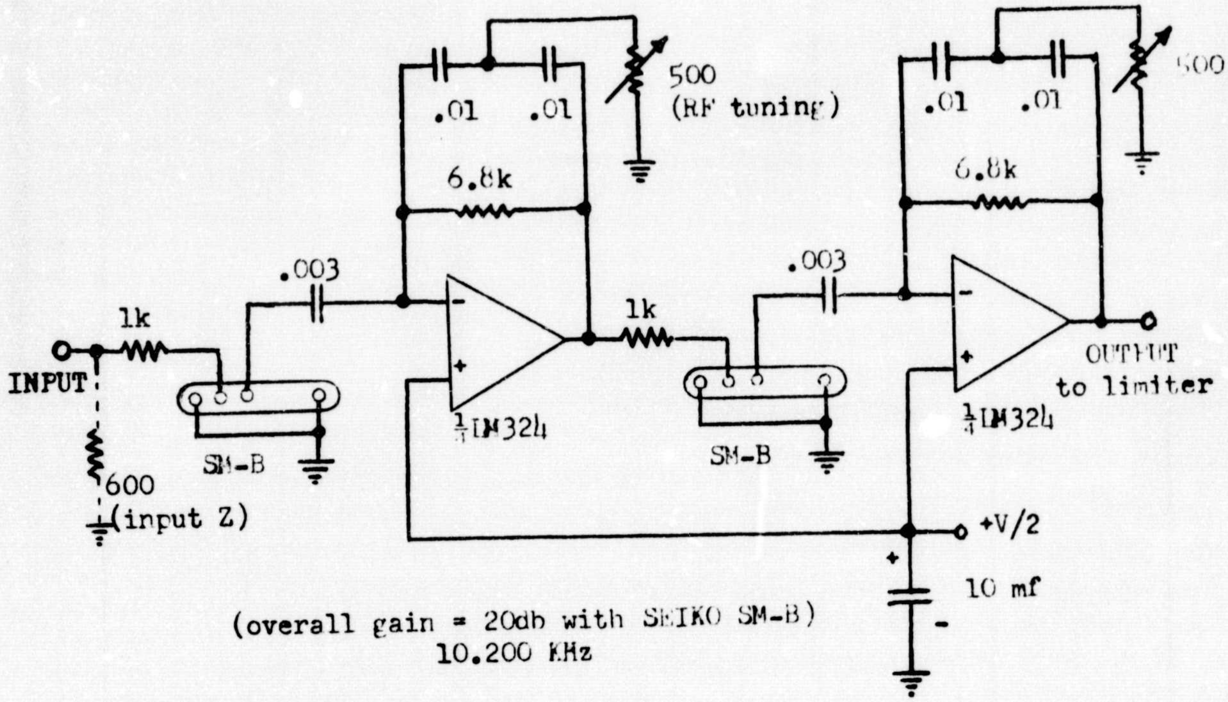

Figure 2. Two-Stage OMEGA Bandpass Filter Circuit.

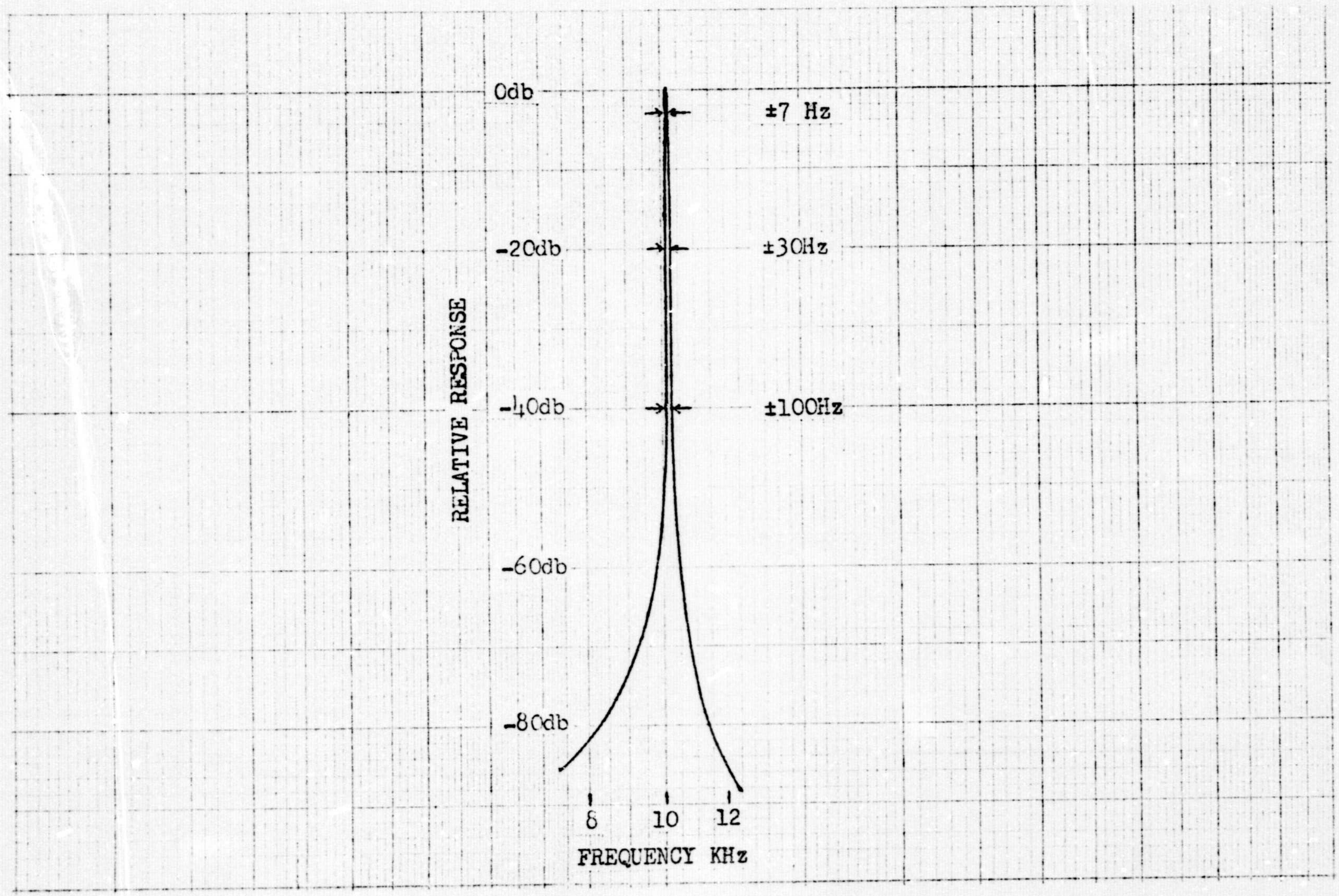

Figure 3. Frequency Response of 2-Stage Filter Circuit with SEIKO SM-B Resonators.

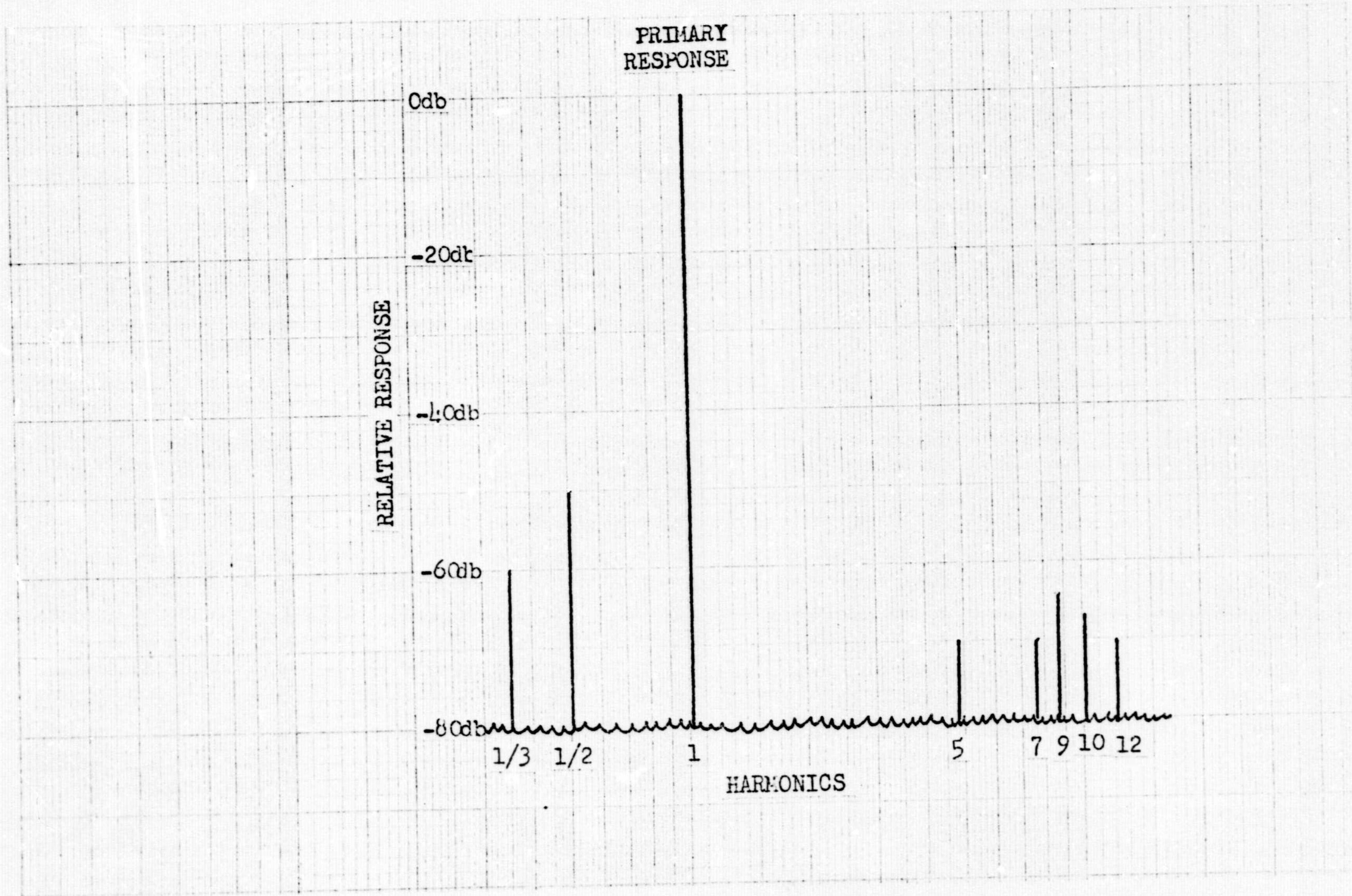

Figure 4. Harmonic Resonances of 2-Stage Filter Circuit.

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