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LOW-NOISE SMALL-SIGNAL AMPLIFIER

D. Neuf and P. Lombardo

Prepared under Navy, Bureau of Ships

Contract N0bsr-87556

Interim Report No. 3

26 January 1963 to 27 April 1963

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DEER PARK, LONG ISLAND, NEW YORK



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- 2 Final Breadboard Configuration

ABSTRACT

During the past quarterly period two single-diode varactor mounts, each having a 40-percent instantaneous bandwidth, were cascaded to yield an overall gain of 10 db from 2 to 3 Gc (3-db points). The noise factor of these combined amplifiers varied linearly from 1.8 db at 2 Gc, to 3 db at 2.8 Gc. The noise factor above 2.8 Gc peaked very sharply to about 5.5 db. The reason for this peak is not yet apparent.

The configuration of the final engineering model has been fixed--four stages will be used and the package will accommodate either the balanced or unbalanced varactor mount.

I. STATEMENT OF PURPOSE

Contract NObsr-87556, Project SR-008-03-01, Task 9391, requires that research and development effort be conducted in the field of low-noise amplifiers with emphasis on four sample devices having the following specifications:

Frequency	Within S-band (2 to 4 Gc)
Gain	15 db (minimum)
Bandwidth	40 percent (minimum)
Noise Factor	2 db (maximum)
Dynamic Power Range	70 db
Cryostatic Cooling	None

II. TECHNICAL DISCUSSION

A. SINGLE-DIODE MOUNT

Our last monthly report indicated that the performance of two single-diode varactor mounts in cascade would be evaluated during the present quarterly period. At that time the largest bandwidth obtainable from the single-diode varactor mount was approximately 20 percent, and a staggered configuration was planned. Recently, the bandwidth of the single-diode varactor mount was extended from 20 to 40 percent by lowering the impedance of the idler resonant circuit. This change increases the negative resistance bandwidth at the signal frequency. Double-tuning was also used in the signal circuit. Because of this increase in bandwidth, two synchronously-tuned units were cascaded, since it was felt that the overall noise factor of a synchronously-tuned combination would be better than a staggered pair.

Figure 1 illustrates the gain and noise factor of this combination as a function of frequency. Four important features were determined by building this combination:

1. At least four stages are needed to ensure a minimum gain of 16 db.
2. An extra circulator (more properly, an isolator) is needed between each stage to minimize "suck-outs" in the pass band.
3. The resultant shrinkage in bandwidth is relatively small at these gain levels. Thus, a 40-percent overall bandwidth is still possible.
4. The noise factor, though higher than the 2-db design goal, is relatively well behaved in the 2.0 to 2.8 Gc range but "peaks up" above 2.8 Gc for no apparent reason.

The sharp increase in noise factor is being investigated to determine if it is inherent in the amplifier or is due to a subtle property of the measurement technique. In either case, several possibilities are available to improve the noise factor. Lower-capacity diodes can be used to raise the idler frequency, thus decreasing the contribution of idler noise at the signal frequency by virtue of the expression

$$NF = (1 + \frac{R_s}{R_g})(1 + \frac{f_1}{f_2})$$

where

R_s = equivalent diode series resistance

R_g = source impedance looking back from
the diode

f_1 = signal frequency

f_2 = idler frequency

Further improvements in noise factor can also be obtained by using a varactor diode with higher self resonance since this will have the effect of a reduced R_g in the previous expression. Finally, some method of cooling other than cryostatic techniques, can be used.

B. BALANCED-DIODE MOUNT

Further progress on the balanced-diode varactor mount has been limited for two reasons. First, we have not received ten low-capacity high-cutoff-frequency varactor diodes that were to be evaluated in this mount. However, we recently ordered enough varactor diodes of the type used in our most successful breadboards to complete four units for delivery. Some of these diodes have already been received. Work on this mount, using the breadboard-type diodes, will continue during the next month. Secondly, more engineering time was devoted

during the past quarter to completion of the two-stage amplifier using single-diode varactor mounts than was anticipated. This was urgently required because, without a parametric amplifier as a second-stage receiver, any accurate noise-factor measurements made on a single stage of low gain would be extremely difficult to obtain. This is due to a large correction factor for the effect of high second-stage noise. For example, when we measure noise factor, a correction is applied to the overall noise factor by virtue of the expression

$$F_1 = F_{12} - \frac{F_2 - 1}{G_1}$$

where

F_{12} = noise factor through parametric amplifier and second stage

F_1 = noise factor of parametric amplifier

F_2 = noise factor of second stage

G_1 = gain of parametric amplifier

Since the gain values we are working with are typically 4 to 5 db, the second-stage correction

$$\frac{F_2 - 1}{G_1}$$

will be excessively large, particularly if a conventional mixer is used as the second stage. This measurement problem is analogous to subtracting two large numbers of relatively good accuracy and expecting the same accuracy of the small difference obtained.

C. FINAL PACKAGE CONFIGURATION

At this time it still is not clear whether the single or balanced varactor diode mount has greater potential with respect to bandwidth and noise factor. Therefore, we have designed a package that can accommodate either mount. Figure 2 is a block diagram of the final package. Four stages are used because this will ensure both adequate gain (16 to 20 db) and high stability.

Generally, the stability of a nondegenerate type parametric amplifier stage is dependent upon the gain achieved, the reverse isolation of the circulator used, and the klystron frequency and power stability. Since the mean stage gain for our final package will be 4 to 5 db, any change in input impedance or circulator characteristics will have only a small effect on the overall gain. Two klystrons are used to ensure a more versatile package. If we can extend the amplification range of either type mount to the 3 to 4 Gc range, it will be possible to cascade and achieve gain from 2 to 4 Gc with the availability of a second pump frequency. The final package will be about 25 inches high by 15 inches deep and it will occupy a standard 19-inch rack.

III. CONCLUSIONS

The gain and bandwidth design goals of this contract can be achieved with four stages using the single-diode varactor mount. However, the noise factor of this configuration is higher than the design goal at the upper end of the band, and the engineering approaches for improving it are limited. Hence, the balanced-diode varactor mount must still be evaluated before any final choice is possible. The dynamic power range specification does not appear to be a problem in either type of mount.

IV. PROGRAM FOR NEXT INTERVAL

Future effort will be used to evaluate the noise factor of the balanced-type mount and extend its amplification into the 3 to 4 Gc range. The noise factor of the cascaded single-diode stages will be compared under synchronous and staggered combinations to determine if the peak in its value above 2.8 Gc can be improved.

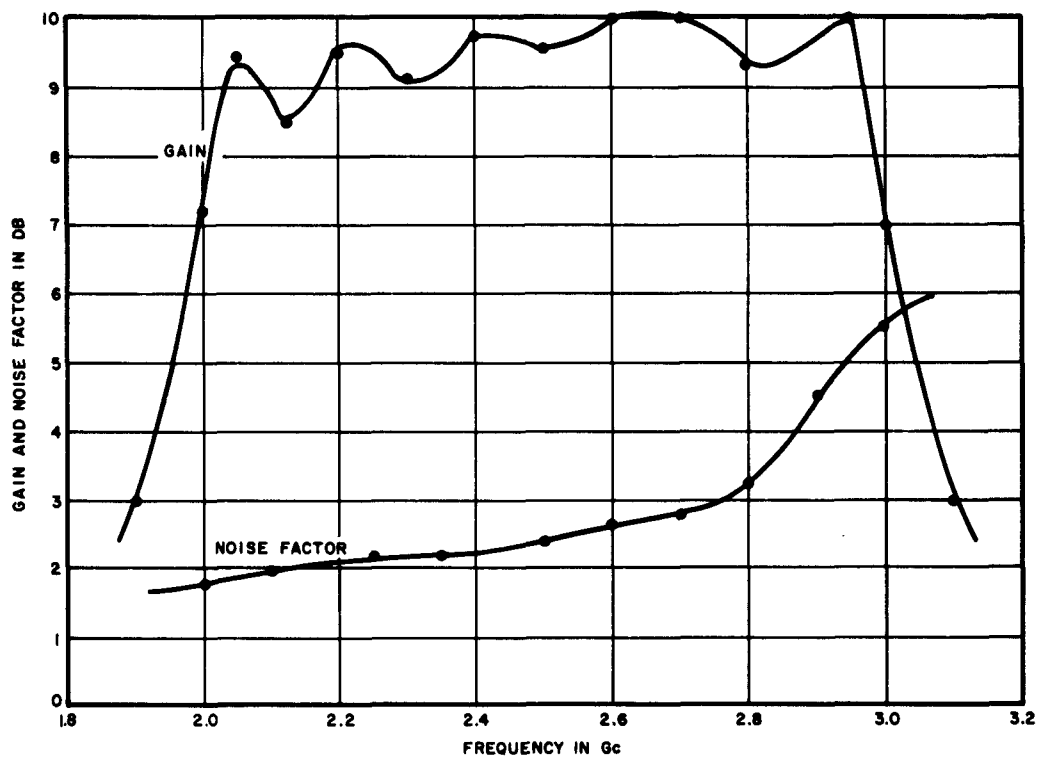
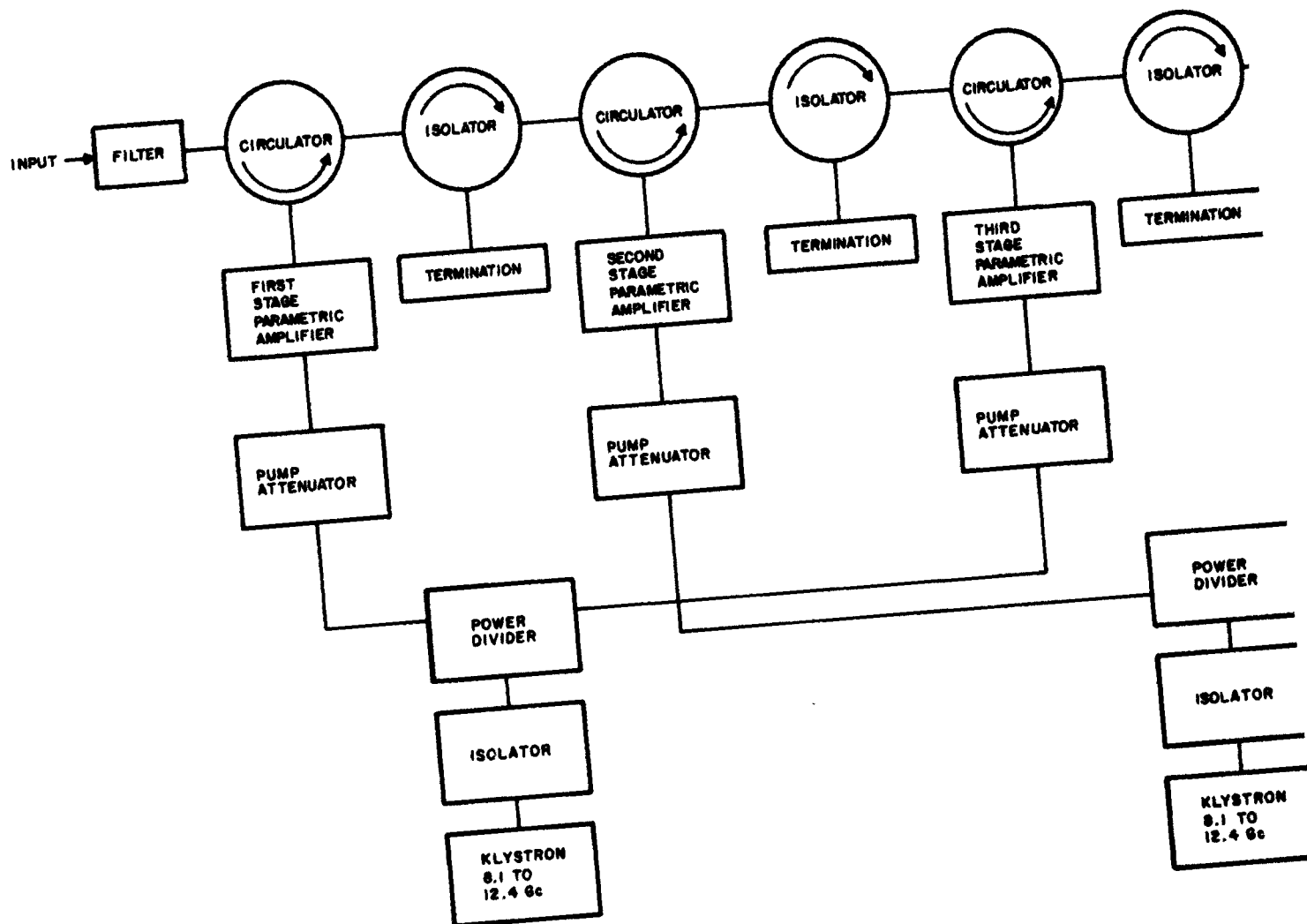


FIGURE 1. GAIN AND NOISE FACTOR AS A FUNCTION OF FREQUENCY FOR TWO SYNCHRONOUSLY TUNED SINGLE-DIODE MOUNTS



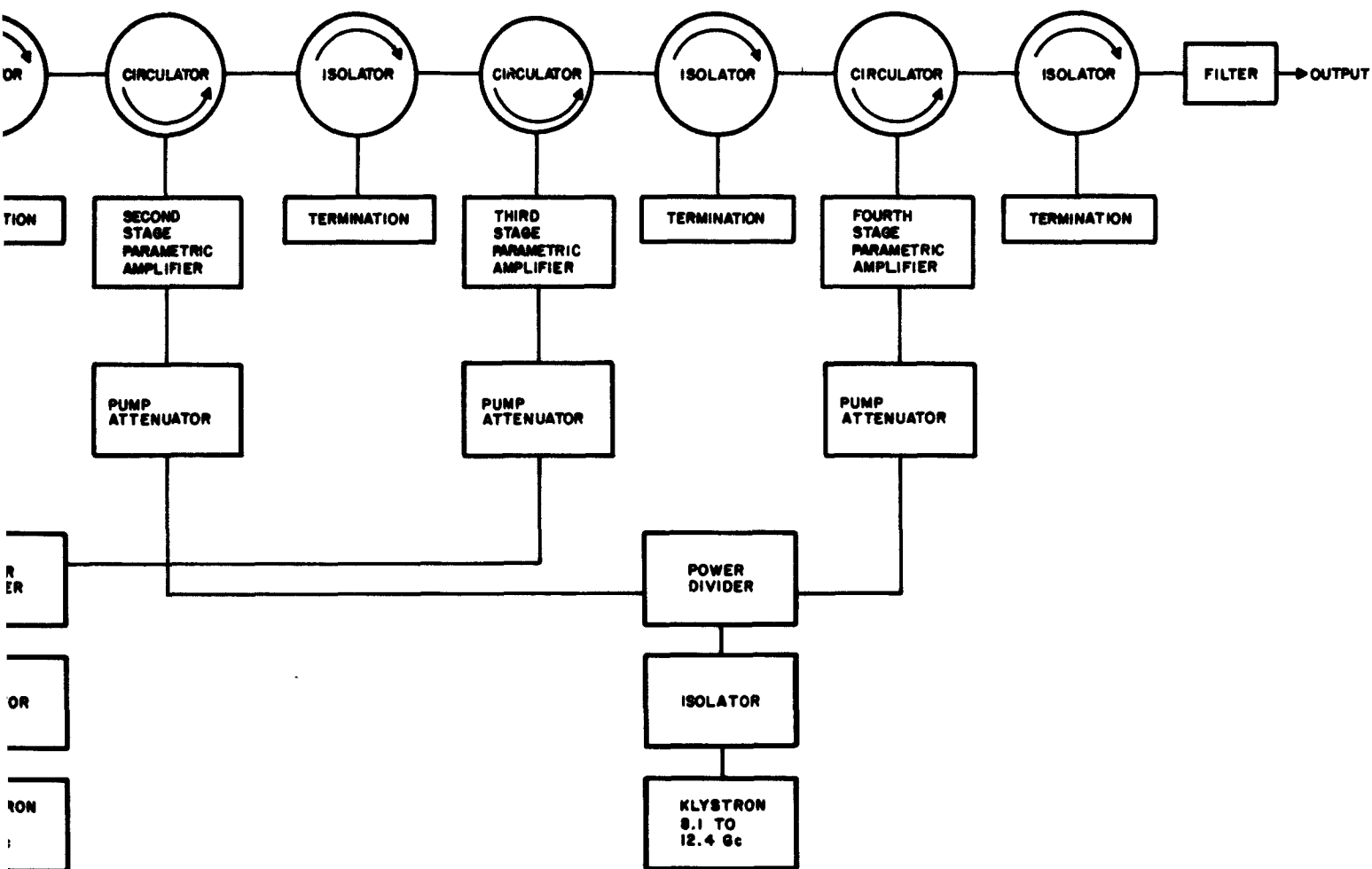


FIGURE 2. FINAL BREADBOARD CONFIGURATION

FIGURE 2

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