A Wide-Band Parametric Amplifier with Triple-Tuned Signal Circuit and Single-Tuned Idler Circuit

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It is the purpose of this letter to present the results of the extension of the work of Egami to the case of a single-tuned idler circuit and a triple-tuned signal circuit. As shown by Egami [1], the input impedance of the double-tuned amplifier is given by

$$Z' = \frac{\left[R_s + jX_1\Omega - \dfrac{1}{1/R_a + jb_a\Omega}\right]}{1 + jb_3\Omega\left[R_s + jX_1\Omega - \dfrac{1}{1/R_a + jb_a\Omega}\right]}. \tag{1}$$

If a series-tuned circuit resonant at the signal frequency is connected across the input terminal Fig. 1, the input impedance is given by

$$Z = \frac{R_s + jX_1\Omega - \dfrac{1}{1/R_a + jb_a\Omega}}{1 + jb_3\Omega\left[R_s + jX_1\Omega - \dfrac{1}{1/R_a + jb_a\Omega}\right]} + jX_3\Omega \tag{2}$$

$$Z = \frac{R_a\left[\alpha(1 + S\tilde{a}) - \dfrac{1}{(1+S)}\right] + jX_3\Omega\left[1 + \eta S\left\{\alpha(1 + S\tilde{a}) - \dfrac{1}{(1+S)}\right\}\right]}{1 + \eta S\left[\alpha(1 + S\tilde{a}) - \dfrac{1}{(1+S)}\right]} \tag{3}$$

where

$$\Omega = \frac{\omega_1}{\omega_{10}} - \frac{\omega_{10}}{\omega} \simeq \frac{2\Delta\omega_1}{\omega_{10}}, \qquad \Delta\omega_1 = \omega_1 - \omega_{10}$$

$$\Omega_0 = \frac{R_s}{a_2 x_{10}} (\tilde{Q}_1 \cdot \tilde{Q}_2 - 1)^{1/2}$$

$$\eta = b_3/b_a, \qquad t = x_3/x_1$$

$$\alpha = R_s/R_a = \frac{1}{\tilde{Q}_1\tilde{Q}_2}, \qquad \beta = R_g/R_a$$

$$\tilde{a} = a_1/a_2$$

$$S = ja_2 \frac{x_{10}}{R_s} \Omega$$

$$R_a = \tilde{Q}_1\tilde{Q}_2 R_s$$

$$b_a = \frac{a_2 x_{10}}{R_a R_s}.$$

The reflection coefficient at $1 - 1'$ port in Fig. 1 is given by

$$\Gamma(S) = \frac{Z - R_g}{Z + R_g}. \tag{4}$$

Thus

$$\Gamma(S) = \frac{\alpha(1+S)(1+\tilde{a}S)(1 - \beta\eta S + S^2\eta\tilde{a}\alpha t) - (1+S)(\beta - S\tilde{a}\alpha t) - (1 - \beta\eta S + \eta S^2\tilde{a}\alpha t)}{\alpha(1+S)(1+\tilde{a}S)(1 + \beta\eta S + S^2\eta\tilde{a}\alpha t) + (1+S)(\beta + S\tilde{a}\alpha t) - (1 + \beta\eta S + \eta S^2\alpha\tilde{a}t)}. \tag{5}$$

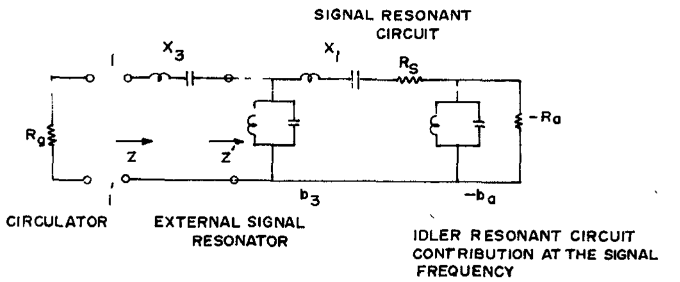

Fig. 1. Signal frequency equivalent circuit of wide-band paramp.

The gain $|\Gamma(S)|^2$ has been calculated with the help of a digital computer and is plotted for the various values of the different parameters. From the results it is observed that the optimum value of slope parameter t of the third-signal resonator was found to be 0.315 for which the ripple in passband is minimum.

As an example, gain $|\Gamma(S)|^2$ is shown in Fig. 2 as a function of Ω/Ω_0, with $\alpha = 0.05$ ($\tilde{Q}_1 \cdot \tilde{Q}_2 = 20$), $a_1/a_2 = 1.0$, $\beta = 1.829$, $t = 0.315$, and varying η. The dotted curves shown in Fig. 2 are for a single-tuned idler and a double-tuned signal while the solid curves are for a single-tuned idler and a triple-tuned signal. As seen from the curves in Fig. 2, the passband ripple and its bandwidth appear to be affected by using a triple-tuned stage, more than by using a double-tuned signal stage. It is apparent from Fig. 2, that the ripple has been decreased whereas the gain remains the same.

Fig. 3 represents the solution corresponding to 10-dB gain, ±1-dB ripple, $a_1/a_2 = 1.0$, and three values of α (or $\tilde{Q}_1 \cdot \tilde{Q}_2$) for double- and triple-tuned signal. This graph shows that a large value of $\tilde{Q}_1 \cdot \tilde{Q}_2$ does not increase the bandwidth ratio Ω/Ω_0 in the triple-tuned case, but the gain increases and the ripple decreases in the passband for the triple-tuned signal when $\alpha = 0.05$ compared to the double-tuned case.

Fig. 4 represents the solution corresponding to 10-dB gain, ±1-dB ripple, $\tilde{Q}_1 \cdot \tilde{Q}_2 = 20.0$, and four values of a_1/a_2 for the double- and triple-tuned signal and the single-tuned idler. From the graph, it is apparent that for $a_1/a_2 = 1.0$, the gain is high and ripple is low for the triple-tuned signal circuit compared to the double-tuned signal circuit.

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REFERENCES

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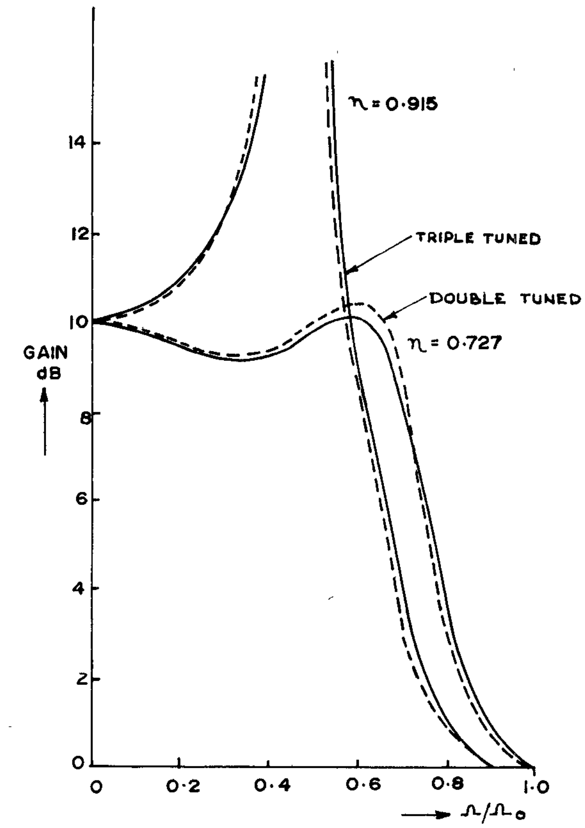

Fig. 2. Theoretical gain frequency response varying the ratio of external signal resonator slope parameter to the negative slope parameter of the pumped diode.——: triple-tuned signal. – – –: double-tuned signal.

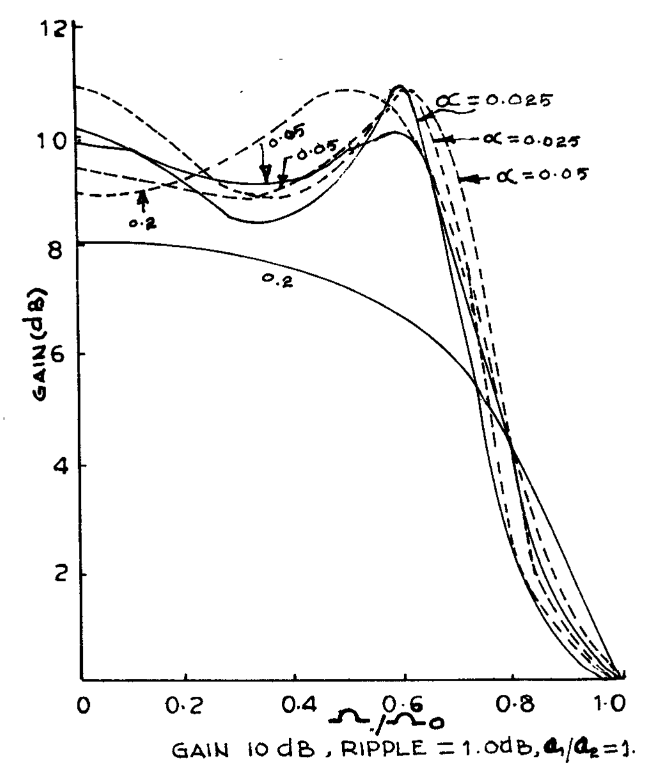

Fig. 3. Theoretical gain frequency response for different α. ——: triple-tuned signal. – – –: double-tuned signal.

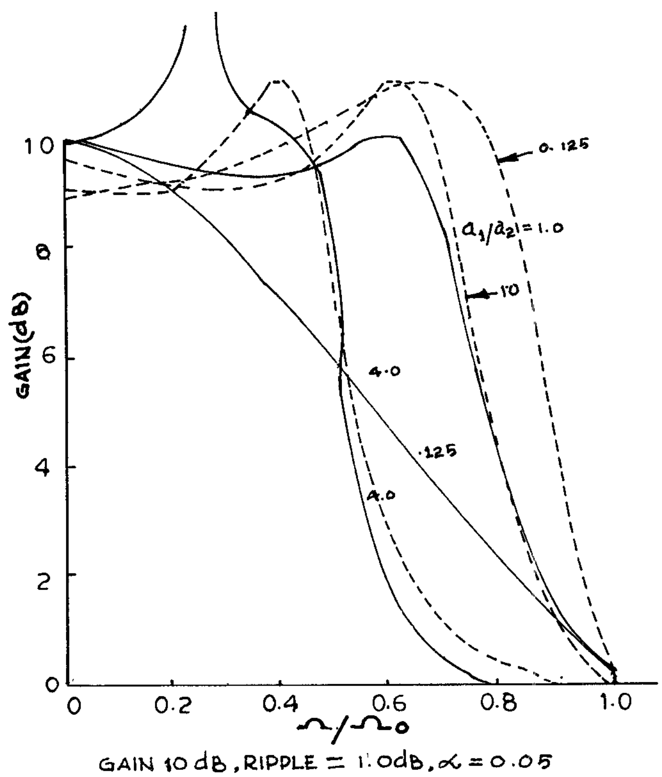

Fig. 4. Theoretical gain frequency response for different a_1/a_2. ——: triple-tuned signal. – – –: double-tuned signal.