Ulrich Rohde (1975)

AL = 884 nH/1000 turns
7 turns = 43.3 uH
1 turn = 0.88 uH

push-pull rf amplifier with wide dynamic range

In many wideband, high dynamic range applications such as antenna distribution amplifiers, input rf amplifiers are required which combine extremely low distortion with low noise figure. In the past both voltage and current feedback have been used to counteract voltage and current distortion. The disadvantage of these circuits is that a stable input impedance can be achieved only over a relatively narrow bandwidth.[6]

Recent research has resulted in a new wideband amplifier design[2,7] which has extremely low vswr at both input and output as well as low noise figure. The second-order intermodulation products can be suppressed nearly 40 dB (over a single stage) by the push-pull arrangement shown in **fig. 4**. Two linear vhf power transistors are used in the circuit, and depending upon the large-signal handling requirements, either the 2N5109 (RCA) or BFR95 (Amperex) may be used. Both of these devices have an F_T of 1600 MHz.

This circuit provides about 11 dB gain and exhibits exceptional freedom from second- and third-order intermodulation products, as plotted in **fig. 5**. The third-order intercept point occurs at an input of about 22 dBm. Three types of feedback are used: *current* feedback through the unbypassed 6.8-ohm emitter resistor, *voltage* feedback through the unbypassed 330-ohm base-to-collector resistor, and *transformer* feedback through a third winding on the wideband transformer to stabilize the input and output impedance. A mathematical analysis of this circuit is presented for interested readers in the appendix.

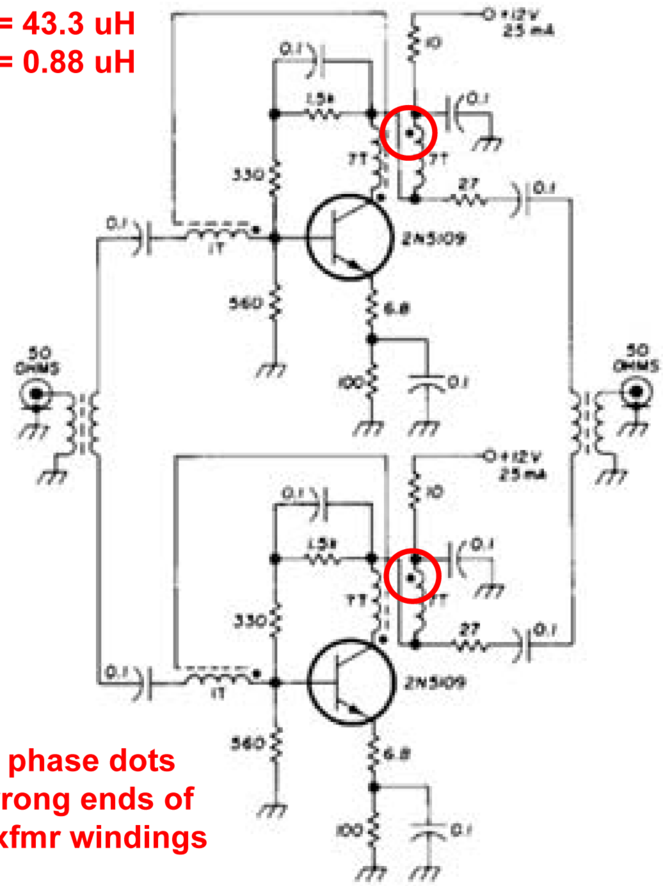


fig. 4. Vhf power transistors are used in push-pull circuit to obtain wide dynamic range shown in fig. 5. Transformers are trifilar wound on Indiana General F625-9-TC9 toroid cores. Equivalent to FT37-77

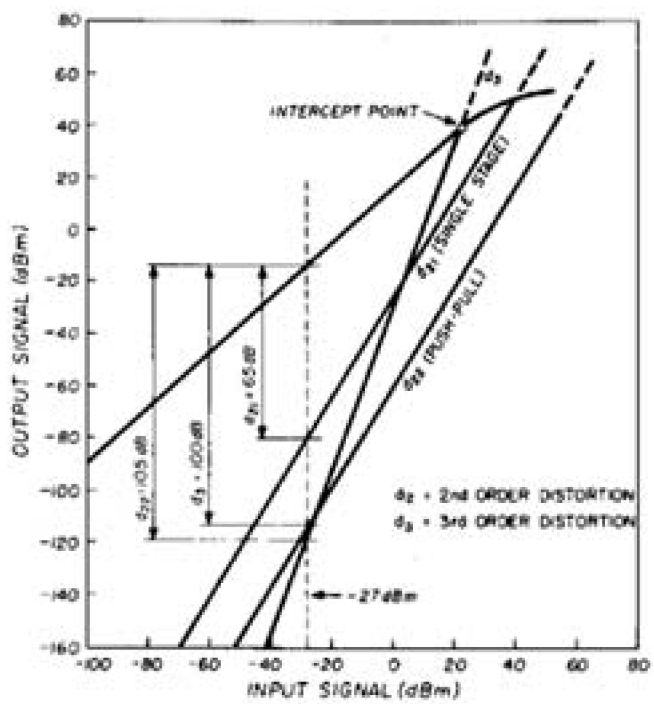
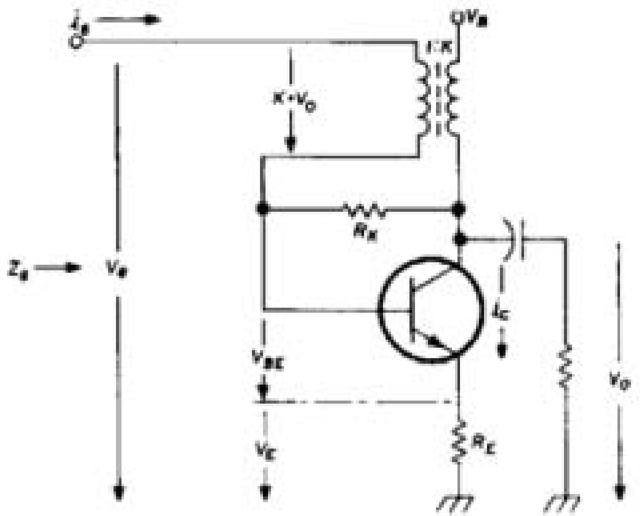


fig. 5. Performance of the push-pull rf amplifier shown in fig. 4. With an input of −27 dBm (two-tone signal, 20 mV each), gain is 12 dB, third-order distortion products are down 100 dB and second-order IMD is down 105 dB. Third-order intercept point occurs at an input of about 22 dBm.

appendix

Since voltage and current feedback may result in input and output impedances which may not suit the design requirements, a wideband toroidal transformer with a high-permeability core (such as Indiana General, F625-9-TC9) can be used to arbitrarily set these impedances. The schematic below



shows an amplifier using a transformer with voltage and current feedback. The input voltage, v_e, input current, i_e, and input impedance, Z_e, are given by the following equations

$$v_e = (k \cdot v_o) + v_{be} + v_e$$

$$i_e = (v_{be} \cdot Y_{11}) + v_{cb}/R_k$$

$$Z_e = \frac{(k \cdot v_o) + v_{be} + v_e}{(v_{be} \cdot Y_{11}) + v_{cb}/R_k}$$

So long as the operating frequency is well below f_T, emitter and collector current are the same. Therefore, the input impedance of the stage will be

$$Z_e = R_k \left(\frac{k + A}{1 - A} \right)$$

where

$$A = \frac{R_E (R_k + R_L)}{(R_E + R_k) R_L}$$

and the required value for the voltage feedback resistor, R_k, is given by

$$R_k = Z_e \left(\frac{1 - A}{k + A} \right)$$

the amplification of the stage is given by

$$A = \frac{1}{k + \frac{R_E (1 + R_k/R_L)}{R_k + R_E}}$$

Since it is advantageous to have a 50-ohm input impedance, and the output impedance of the stage is approximately 150 ohms, the collector winding is split to build a 4:1 transformer. Under these conditions the input impedance, Z_e, output impedance, Z_o, and voltage gain, A, are given by

$$Z_e \approx (k \cdot R_k) + \frac{R_E}{2}$$

$$Z_o \approx \frac{R_E}{2k}$$

$$A = \frac{1}{k \left(1 + \frac{R_E}{2k \cdot Z_L} \right)}$$

The constant k, which determines the turns ratio between the base and collector coil (1:7:7 in **fig. 5**), can only be an integer. To obtain optimum performance in many cases, therefore, one of the values may have to be a compromise. In the circuit of **fig. 5** the output impedance was only 23 ohms so a 27 ohm resistor had to be placed in series to obtain the desired 50-ohm output impedance.