An Active Reflector Circuit

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***Abstract*— A possible circuit for a reflector antenna.**

I. Circuit Proposal

A top-view illustration of the arrangement of an active reflector node is shown in Fig. 1 (with proposed dimensions). Imagined is a loop antenna to which a chip is flip-chip connected. On the chip is the active circuit arranging for electromagnetic energy to be reflected with gain from the structure.

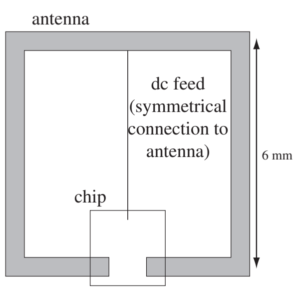

Fig. 1. Artist's impression of possible active reflector node.

A proposal for the circuit is shown in Fig. 2. The design is

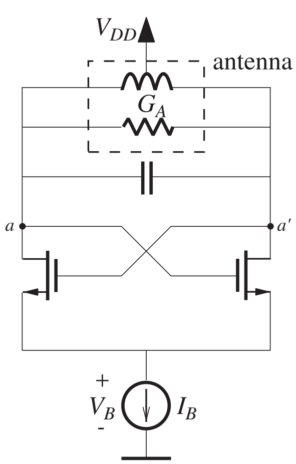

Fig. 2. A possible active reflector circuit.

straightforward. Employing a long-channel approximation for the behaviour of the cross-coupled MOSFET pair the negative conductance seen looking into the active circuit between terminals a and a' is

$$G_C = -G_R = \frac{-g_m}{2} \tag{1}$$

Many thanks to the friends of FishLab.

where g_m is the transconductance of one MOSFET. Recall from [1] that the gain of an active reflector can be expressed as the square-modulus of reflection coefficient

$$\Gamma_c = \frac{(1+K_G) - j(1+K_B)Q_A}{(1-K_G) + j(1+K_B)Q_A}. \tag{2}$$

For a reactive match this means that

$$\Gamma_{c,m} = \frac{(1+K_G)}{(1-K_G)} \tag{3}$$

where

$$K_G = \frac{G_R}{G_A} = \frac{g_m}{2G_A}. \tag{4}$$

using the relationship (again only valid in the long-channel MOSFET approximation)

$$g_m = \frac{I_B}{V_{on}} \tag{5}$$

where, given the circuit in Fig. 2 and MOSFETs with a threshold voltage V_T the on-voltage is given by

$$V_{on} = V_{DD} - V_T - V_B. \tag{6}$$

With the above relations we can state

$$K_G = \frac{G_R}{G_A} = \frac{I_B}{2G_A(V_{DD} - V_T - V_B)}. \tag{7}$$

At the same time, the dc power consumed by the negative resistance (ignoring support circuitry such as that needed to complete the current source I_B) is

$$P_{dc} = V_{DD} \cdot I_B \tag{8}$$

so that we can also state

$$K_G = \frac{G_R}{G_A} = \frac{P_{dc}}{2G_A V_{DD}(V_{DD} - V_T - V_B)}. \tag{9}$$

Some simple calculations on small loop antennas (2 to 6-mm) carried out earlier resulted in antennas with $G_A \approx 10^{-5}$ S and Q-factors around 200. The reflected power gain for such an antenna as a function of the dc power dissipation is shown in Fig. 3. As shown, an extremely low amount of dc power (less that 6 μW) is needed to realize large reflector power gains.

Clearly, we cannot get more power out of the antenna than we put in (via the supply V_{DD}). Thus, although very little power is needed to adequately drive the antenna (i.e. with high gain), very little power is actually radiated as well. Such is the case with small antennas (a future technical note will touch on this).

As a contrast, consider an antenna for which $G_A = 1/100\frac{1}{\Omega}$. In this case our gain-dc power relationship looks like that shown in Fig. 4. Not surprisingly, the dc power needed to maintain the same reflector gain as the active antenna considered in Fig. 3 has increased by three orders of magnitude (to values less that 6 mW).

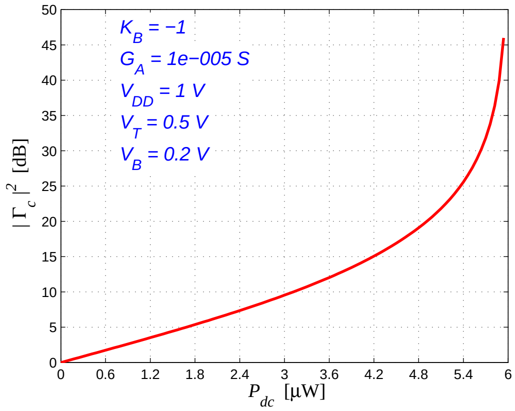

Fig. 3. Power gain of a reflector antenna versus dc power consumption of active component.

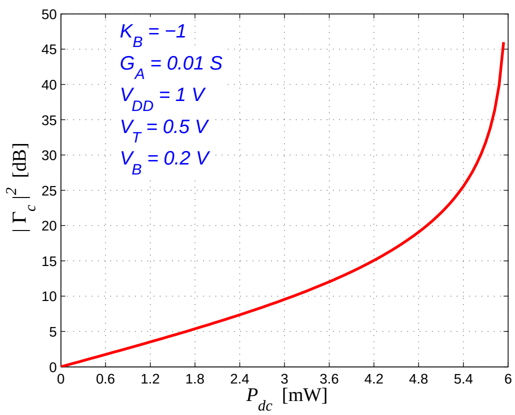

Fig. 4. Power gain of a reflector antenna versus dc power consumption of active component.

REFERENCES

[1] S. Magierowski, "Active analog reflector antennas: Scattered power," Tech. Rep., May 23 2007.