BROAD BAND ACTIVE RECEIVING MICROSTRIP ANTENNA FOR DCS-UMTS

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Abstract: This paper presents an active receiving patch antenna at 1600MHz-2000MHz band (it has been obtained a flat G/T parameter with a value of around -20dB/k). Then, G/T has been increased over 10 dB compared with the measured value for the passive antenna. An increase in EIRP between 13-15 dB (with the ATF34143) has also been measured, depending on the bias conditions, for a bandwidth between 1500 and 2200 MHz. The proposed active antenna has been designed from a stacked patch antenna and directly feeds the input of a resistive equalised broadband amplifier.

I. INTRODUCTION

The demand on integrating efficiently several communication services in the same antenna (for instance DCS and UMTS) has made antenna engineers design multifrequency or broadband antennas. Several techniques have been used to increase the bandwidth of a patch radiator [1]: external matching circuit, matching in the radiating surface of the patch, inclusion of coplanar parasitic elements, inclusion of resonant disturbances and use of stacked elements. The last one has been very popular in broadening an antenna bandwidth or in constructing multifrequency antennas. **Figure 1** has been taken from [2], corresponds to the asymmetric stacked patch antenna (with a positive displacement) and represents its reflection response. It can be seen its behaviour as a dual frequency antenna.

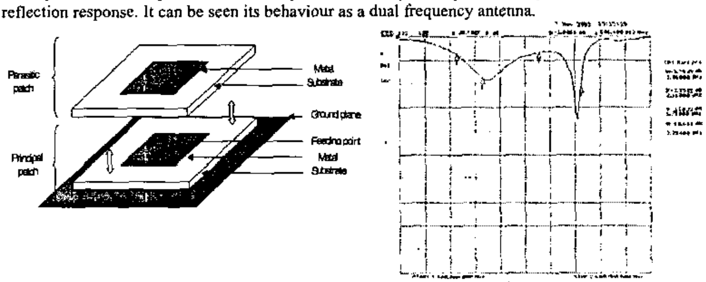

Figure 1: Dual frequency passive asymmetric stacked patch antenna

The use of active antennas improves radio links parameters as EIRP (in transmission) or G/T (in reception). Most active antennas designs are narrowband due to both the patch filtering properties and the amplifier input matching network. In addition to the advantage of increasing the EIRP, the inclusion of a resistive equalised broadband amplifier, feeding directly the antenna, broadens greatly the reflection antenna bandwidth and also presents wider gain bandwidth compared to the passive counterpart. The main problem on designing a broadband reception antenna is to keep the noise under reasonable level so that the amplifier itself would be very near the minimum noise figure of the FET and a clear increase in G/T can be increased.

This article presents a new approach for the design of amplifier-type active broadband receiving antenna: the output of the antenna is directly connected to the input of the broadband amplifier. The amplifier has been done by using a resistive equalisation technique high impedance lines. The input line (and the resistor connected to it) equalises low frequencies and does not affect the noise behaviour at the work frequency. The output impedance line (and its corresponding resistor) equalises upper frequencies but its effect on the overall noise power is very low. In this way, the proposed antenna increases its bandwidth thanks to the resistive loading and its gain thanks to the active antenna and maintains a reasonable noise level thanks to the input high impedance line. The design of broadband active amplifier radiators is an innovative topic of research. In [3] a broadband reactive equalised active antenna was presented. That active antenna was not directly fed to the amplifier what increased the losses in the corresponding radio-links. Besides no measurements of the active antenna noise were presented (amplifier noise

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measurements were only presented). In [4] an active broadband transmitting patch antenna was presented. It was directly connected to the amplifier so an increase in the transmission radio link parameters was obtained. In this paper the technique presented in [4] has been modified to be used in low noise broadband active receiving antennas.

II. ANALYSIS OF ACTIVE ANTENNAS

Other topic in fashion is the use of active antennas to improve radio links parameters as EIRP or G/T. This concept provides a new paradigm for designing modern microwave systems and can be explained from either the circuit or the antenna point of view [4-5]. From the microwave engineer's point of view an active antenna integrates the active RF front-end on the antenna directly. It can be seen that the active device and the antenna are treated as a single entity. From a circuit point of view, the active antenna can be considered as an RF amplifier connected directly to the antenna load; then, a "realized gain" has sometimes [3] been defined as follows

$$G_a(\theta,\phi) = G_T \cdot G_{rad}(\theta,\phi) \tag{1}$$

where G_T is the transducer gain of the amplifier with the radiator as its load, $G_{rad}(\theta,\phi)$ is the gain of the passive radiator. In [3] it is said that "this gain definition can result in a gain value substantially larger than the passive radiator directivity". However, this definition can not be accepted from the antenna theory point of view since the antenna gain can never be larger than the directivity of the antenna. Then, for an active transmitting or receiving antenna, a concept of the increase of EIRP (Equivalent Isotropic Radiated Power) could be applied. This definition is coherent since it is comparing the EIRP transmitted by a passive antenna and its counterpart transmitted (or received) by the active antenna. Besides, the separation proposed in (1) can not be made for two reasons: first, the two members of the product in (1) can not be measured since they can not be physically separated. Second, the expression is only correct when the impedance of the radiating element is real and matches the amplifier through a matching network. Then, the increase or EIRP can be given as:

$$\Delta EIRP = 10\log\left(\frac{EIRP_{ACT}}{EIRP_{PAS}}\right) = 10\log\left(\frac{|s_{21ACT}|^2}{|s_{21PAS}|^2}\right) = G_{ACT}(dB) - G_{PAS}(dB) \tag{2}$$

where sub indices $_{ACT}$ and $_{PAS}$ correspond to the active or passive link parameters.

The other parameter to be studied in active receiving antennas is G/T. For a receiving system it can be estimated from individual measurement of its different components. Unfortunately, this is not the case for a receiving active antenna, where the radiator and active circuitry can not be separated and an individual measurement is not possible. Then, the measurement procedure can be summarised as follows:

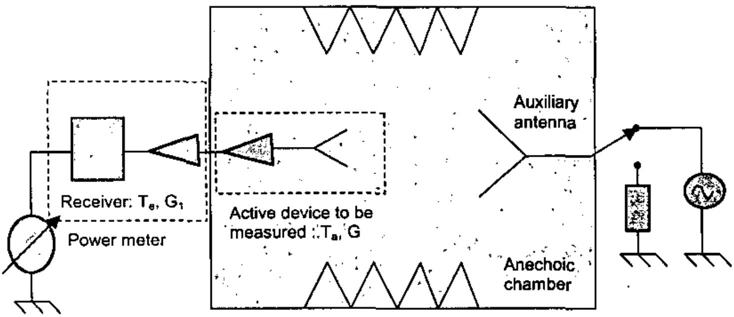

Figure 2: Measurement system outline

First: measurement of the received power with the generator OFF ($P_{off} = k(T_a + T_e)G_1 B$). Secondly: measurement of the power with the generator ON ($P_{on} = k(T_a + T_e)G_1 B + \lambda^2/4\pi \cdot G_{RX} G_1 S_0$). Third:

Do the quotient between P_{ON} and P_{OFF}: $Y = P_{on}/P_{off} = 1 + \left(\lambda^2/4\pi \cdot G_{RX} S_0\right)/k(T_a + T_e)B$. Then, the merit figure G/T is given as:

$$\frac{G}{T} = \frac{G_{RX}}{T_a + T_e} = (Y-1)\cdot\frac{kB}{\lambda^2 \cdot S_0/4\pi} \tag{3}$$

S_0 is directly measured with a known passive antenna.

III. DESIGN OF BROADBAND ACTIVE RECEIVING ANTENNAS

From the model of a FET amplifier [5] it can be shown that the minimum noise figure is given as:

$$F_{\min} = 1 + 2G_n \cdot R_{cor} + 2\sqrt{R_n \cdot G_n + (G_n \cdot R_{cor})^2} \tag{4}$$

where subindex n corresponds to the internal impedance or admittance of the noise generators and subindex cor refers to the correlation between noise generators. It can be shown that for a broadband matching of the optimal source impedance which results in the minimum noise figure we need a circuit that approximately imitates the behaviour of a negative capacitor. It has also been seen that the input impedance of ATF34143 moves clockwise with frequency and, therefore, the optimal source to obtain minimum noise should move counterclockwise with frequency. This counterclockwise measurement can be obtained with matching network with resonances. Then, a lossy resonant circuit can imitate the behaviour of a negative capacitor or inductor. Then, on the Smith chart the trajectory of the resonant circuit approaches the minimum noise impedance. This resonant circuit can be done with the patch itself. In this way, it could be said that input patch impedance presents an optimal behaviour for the construction of broadband low noise active antennas.

Unfortunately this is not exactly as it has been presented in the previous paragraph and it is very difficult the patch impedance with the minimum noise impedance for a great frequency bandwidth margin. In order to increase that margin a modification of equation 4 could be done. In this way, Niclas proposed to modify G_n and Y_{corr} to design broadband amplifiers. In [5] it can be seen that this modification, for the case of low noise amplifier, is mainly affected by the value of the gate conductance. If this gate conductance would be connected to the antenna via high impedance lines, its effect at higher frequencies would be significant less important than at lower frequencies. In this way one of our critical design parameters is the gate conductance and the high impedance input line and the amplifier will be optimised attending these values. Then, a noise figure lower than 0.5 dB has been obtained for a bandwidth between 1.6 GHz and 2.45 GHz.

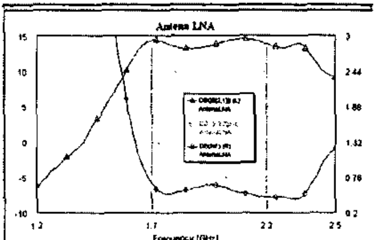

Figure 3: Noise and gain of the amplifier with the antenna as source impedance

IV. MEASUREMENTS OF THE ACTIVE RECEIVING ANTENNA

Measurements have been done with an auxiliary log-periodic antenna that covers the whole bandwidth (GSM1800 and UMTS). One passive antenna (identical to the passive radiator used for the active integrated antenna) and one active antenna have been used to measure the link parameters. Measurements of the reflection coefficient and the transmitted parameter for the same radio link as in the passive antenna have shown good agreement with the simulation results. Figure 4 shows the transmission parameter where an improvement in EIRP increase of 13-15 dB has been achieved, depending on the bias conditions, over a band from 1500 to 2220 MHz (this implies a band of 35% in front of the 20%

bandwidth of the original passive antenna). The reflection coefficient has been improved by the active element resulting is lower than 10 dB for a bandwidth from 1GHz to 3 GHz.

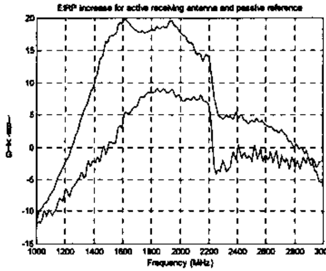

Figure 4: Measured transmission coefficients between reference antenna and passive or active microstrip antenna

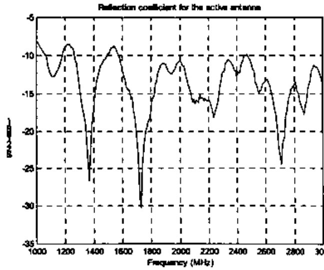

Figure 5: Measured reflection coefficient for the active microstrip receiving antenna

The noise performance of the amplifier type receiving microstrip antenna is of great importance in practical applications and it has been measured via the G/T parameter. It can be seen that G/T is -20dB/K in a bandwidth between 1600 and 2000 MHz. That implies an increase of more than 10 dB over the corresponding parameter of the passive antenna.

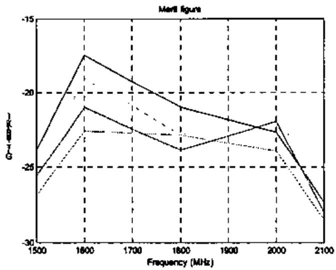

Figure 6: G/T measurements for the active microstrip receiving antenna for four bias conditions

V. CONCLUSIONS

The technique of resistive loading for construction of active antennas has been shown as a suitable one to increase both the bandwidth of the antenna, EIRP and G/T parameter. An antenna working in the DCS-UMTS has been presented with an equivalent gain of 13-15 dB (depending on bias conditions) and a gain bandwidth of 35%. Relative planar G/T of around -20dB/K has also been obtained.

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