ACTIVE EQUALISED BROADBAND TRANSMITTING PATCH ANTENNA FROM A DUAL FREQUENCY ONE

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Abstract: This paper presents an active transmitting patch antenna working in the 1650MHz-2300MHz band. An increase in EIRP of 11 dB has been achieved by measuring both the passive and active radiator. The proposed active antenna has been designed from a dual frequency stacked patch antenna (1785-2250 MHz) fed directly through the output probe of a resistive equalised broadband amplifier.

I. INTRODUCTION

Nowadays the topic of designing and constructing multifrequency and broadband antennas is in fashion. One of the most important reasons for this is the demand on integrating efficiently several communication services in the same antenna (for instance DCS and UMTS). Several techniques have been used to increase the bandwidth of a patch radiator [1-2]: 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. Recently, a new strategy based on the electrical displacement of one patch in front of the other in an antenna composed of two stacked patches has been proposed to broaden the bandwidth or achieve dual frequency antennas [3]. An impedance bandwidth of 25-30% can be obtained with this topology by stacking two canonical patches (rectangular or circular) and displacing one of them in front of the other. Resistive equalisation technique has been discarded as a broad banding one due to the great gain loss that they caused.

Other topic in fashion is the use of active antennas to improve radio links parameters as EIRP or G/T [4]. Most active antennas designs are narrowband due to both the patch filtering properties and the amplifier input matching network. Substitution of passive antennas by active ones would keep the initial aim of broadening the antenna bandwidth without decreasing the antenna gain.

This paper presents an active transmitting antenna that makes use of a broadband amplifying function. This function is realised by using a resistive equalisation technique. This resistive load is simultaneously a part of the proposed broadband amplifier and resistive load for the patch antenna. In this way, the proposed antenna increases its bandwidth thanks to the resistive loading and its gain thanks to the active antenna. In [5] a broadband active radiator was obtained, however it has a serious drawback since resistive matching networks between the antenna and the amplifier are used. The suppression of these networks improves the gain response of the antenna.

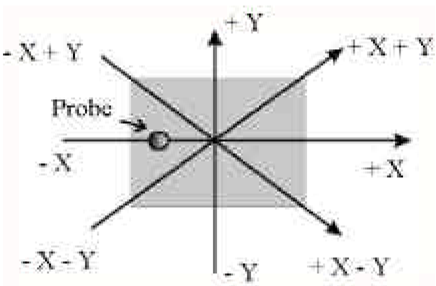

Figure 1: Sketch of the parasitic patch with the meaning of the corresponding displacements

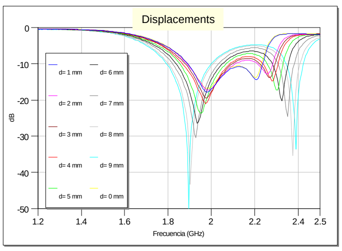

Figure 2: Simulated reflection coefficients for two asymmetrical stacked patches taking the positive displacement in the E-plane as parameter.

II. DUAL FREQUENCY PASSIVE ANTENNA

The original passive antenna is a set of two stacked patches where the upper patch has been displaced in the E plane. Although the displacements in the E plane in a positive sense (see figure 1) are better to increase the bandwidth the original passive antenna presents a negative displacement to appreciate more clearly the effect of the equalisation (H plane displacements are discarded [3]). The antenna has been designed to resonate at DCS and UMTS frequencies (1.785 GHz and 2.25 GHz). A 5 mm displacement results in a VSWR<2 in the whole region between the proposed resonant frequencies. Figure 3 shows the measurement of the reflection coefficient of the proposed antenna for a 5 mm negative displacement. Although the broadband design could have been improved by means of electrical displacement, it has not been done since our final aim is to obtain a broadband transmitting active antenna that overcomes the drawbacks of the corresponding passive antenna and will only be our starting point. Figure 4 shows the gain for the passive antenna. At the central frequency a gain of 5-6 dBi has been measured.

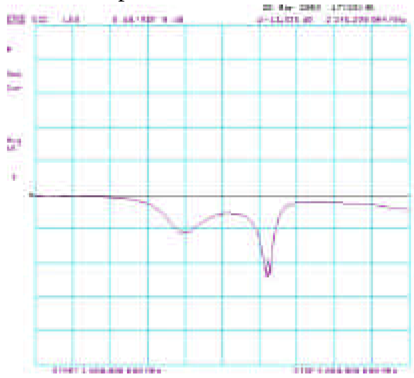

Figure 3: Measured reflection coefficient for a 5 mm negative displacement in E direction.

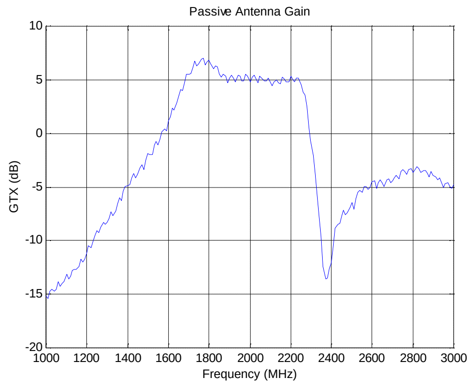

Figure 4: Gain for the passive antenna.

III. EQUALISED BROADBAND ACTIVE TRANSMITTING ANTENNA

The concept of broadband amplifier has been extensively studied. Three principles have been mainly proposed: the matched feedback amplifier, the lossy equalised amplifier and the distributed amplifier. From our point of view it is not clear which shows the best performance since all of them are compact and simple to construct. However our final aim of integrating the amplifier in an antenna and equalise the antenna impedance at the same time made us propose the lossy equalised technique as the most suitable.

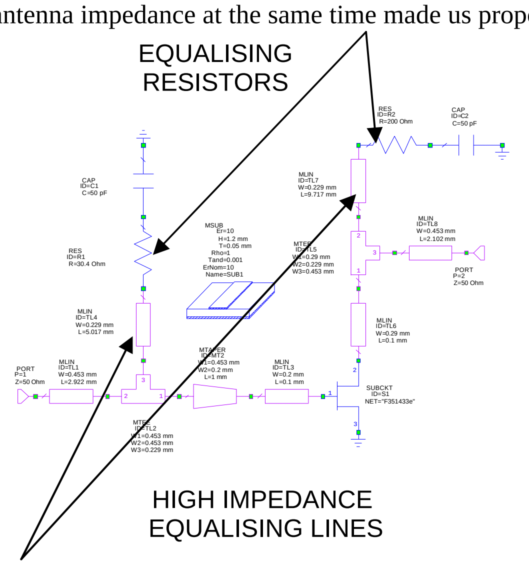

Figure 5: Schematic of resistive equalised amplifier.

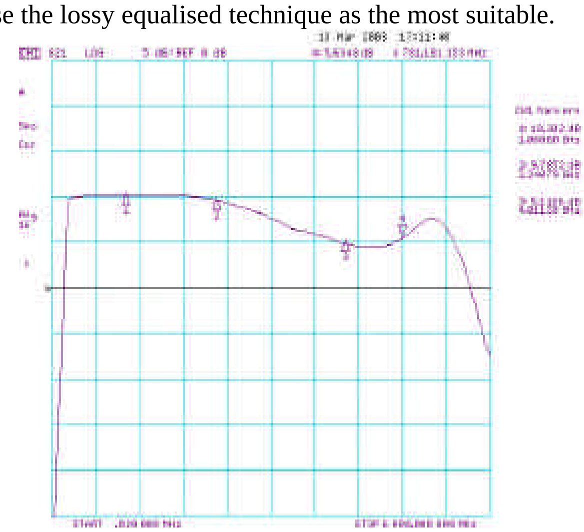

Figure 6: Measured parameters for the proposed amplifier.

The ATF-35143 from Agilent has been the FET transistor used to build the amplifier. Figure 5 shows the schematic of the proposed amplifier. Four parameters (two at the input and two at the output) are critical to reach a broadband amplifier: output and input resistors and their corresponding high impedance lines [6]. Since the gain decreases rapidly with frequency the resistive loss needs to be gradually reduced with frequency which is accomplished by the high impedance shunt stubs in series with the corresponding resistors R_D and R_G (where sub indices mean drain and gate respectively). Figure 6 shows the gain measured of the proposed amplifier for V_{DS}= 4.9V and V_{GS}=0.1 V. The VSWR is lower than 2.

The integration of a broadband amplifier in the set of stacked patches constitutes a new entity [7] that is shown in figure 7. The output load of the amplifier has been changed by the load of the dual frequency passive antenna. The output resistor is changed in a way that has to take into account, at the same time, the antenna impedance parameter and the output parameters of the corresponding equivalent circuit of the FET transistor. Measurement of the increase in EIRP has been done following the procedure shown in 1-3:

$$S_{21}(dB)=G_{TX}(dB)+G_{RX}(dB)-L_A(dB)\ \mathrm{L_A}\text{ free space losses} \qquad (1)$$

$$\text{Gain of the transmitting antenna: } G_{TX}(dB)=S_{21}(dB)-G_{RX}(dB)+L_A(dB) \qquad (2)$$

$$\text{Increase in EIRP: } \Delta=10\log\left(\frac{|s_{21ACT}|^2}{|s_{21PAS}|^2}\right)=10\log\left(\frac{EIRP_{ACT}}{EIRP_{PAS}}\right)=G_{ACT}(dB)-G_{PAS}(dB) \qquad (3)$$

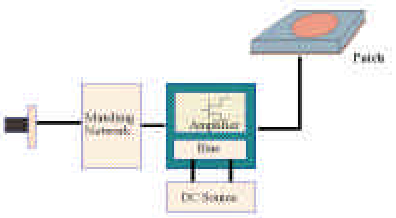

Figure 7: Block diagram of an active integrated antenna

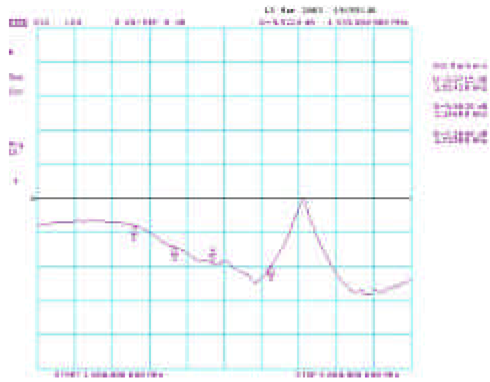

Figure 8: Reflection coefficient of the active antenna.

Several active antennas have been built and measured. First of all an active antenna consisting of the broad band amplifier measured in figure 6 with equalising resistors of 70 and 90 ohms was directly integrated in the patch radiator. Results have been obtained for maximum gain; this implies a bias network for V_{DS}= 4.9V and V_{GS}=0.1 V. Figure 8 shows the reflection coefficient at the input of the active antenna; the impedance bandwidth has been considerably increased in front of the passive one shown in 3. Figure 9 shows an increase of EIRP of 8-11 over a band from 1650 to 2300 MHz. However, the equalisation in the upper part of the band is not appropriate and a ripple of the active antenna (around 2 dB) appears due to the inefficient equalisation in higher frequencies.

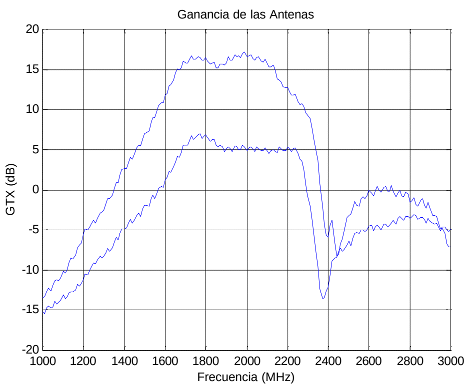

Figure 9: Comparison between passive and active antenna gains* V_{DS}=4.9, V_{GS}=0.1

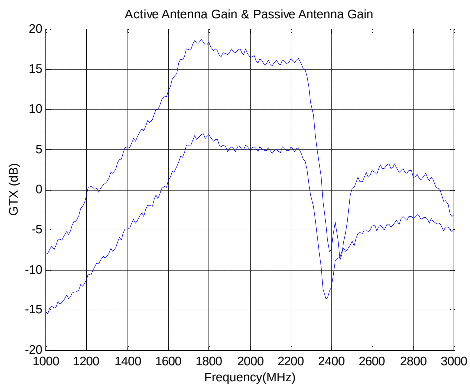

Figure 10: Comparison between passive and active antenna gains* for V_{DS}=3.1 V, V_{GS}=0 V

A study of the influence of the equalisation resistors has been carried out to reduce the ripple in the equivalent s_{21} parameter (or increase in EIRP). Then, new values for gate and drain resistors are 10 and 50 ohms respectively. Bias conditions are V_{DS}= 3.1 V and V_{GS}=0 V what maintains the transistor in its linear region while giving a maximum planar gain over 10 dB. Figure 10 shows the gain of both active and passive antenna (*it must be taken into account that the concept of gain in the active antenna refers to the parameter obtained directly in the link budget by solving equation 2 and has no relation with the antenna radiation and beamwidth characteristics). Figure 11 shows the increase in EIRP between the active and the passive antenna, it can be seen that a ripple lower than 1 dB has been obtained through a bandwith from 1650 to 2350 MHz with an increase in EIRP between 11 dB and 12 dB.

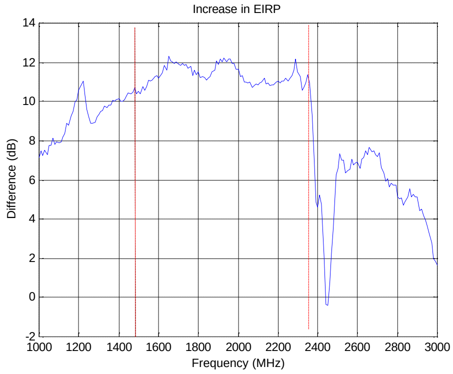

Figure 11: Increase in EIRP between active and passive antenna.

Finally, a spectral analysis must be done since the amplifier can have harmonic distortion. These frequencies must be filtered by the antenna so the harmonic active antenna response is similar to the passive one. Figure 12 shows the spectrum of the broadband amplifier presented at the beginning of this section and the spectrum of the integrated active antenna. Although the amplifier has been designed in linear region, a 10 dBm tone puts the amplifier over the 1 dB compression point making the second and third harmonic be at – 2 dBm level with an isolation of only 17 dB. The patch antenna, however, is able to filter in an efficient way the second and third harmonic frequencies (and the subsequent ones) with isolation greater than 50 dB.

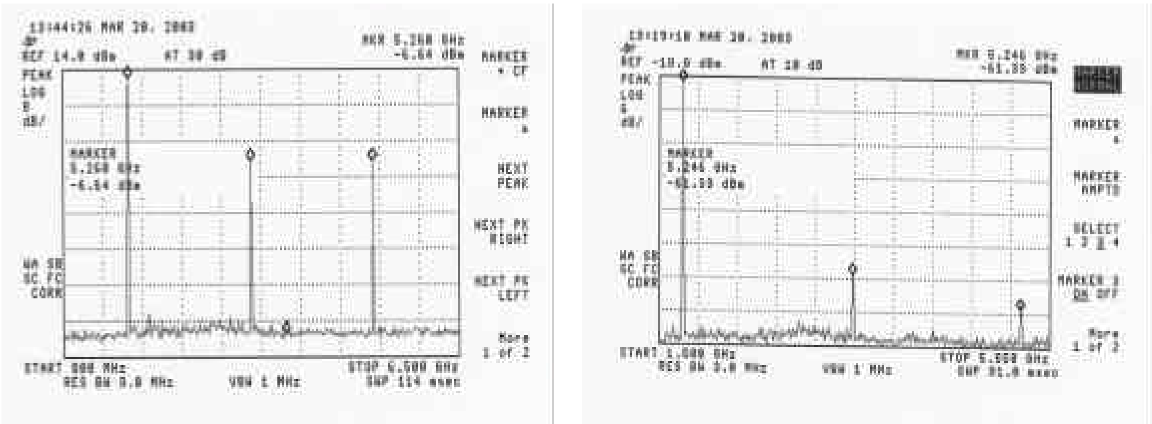

Figure 12: Spectrum of broadband amplifier (left side) and active antenna amplifier (right side)

IV. 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 and the corresponding EIRP. An antenna working in the DCS-UMTS has been constructed from a dual frequency antenna at 1785-2250 MHz. An equivalent gain greater than 11 dB, ripple of 1 dB and a gain bandwidth greater than 34% have been obtained in the resistive equalised active antenna.

V. REFERENCES

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