Conclusion: It is found that both the radiation sensitivity and stability of *p*MOS transistors, biased with 9 V, carrying gate oxides grown by thermal oxidation followed by CVD oxidation, are completely satisfactory. On the basis of results presented here, as well as our other experimental investigation of *p*MOS dosimeters under a variety of bias conditions (negative and zero gate bias), it can be concluded that an oxide field above a certain value is required in order to achieve linearity of threshold voltage shift with dose.

12th July 1993

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MEASUREMENT TECHNIQUE FOR ACTIVE MICROSTRIP ANTENNAS

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Indexing terms: Microstrip antennas, Active antennas, Antenna measurements

A novel technique is presented for measuring the transducer power gain of an amplifier which is an integral part of an active microstrip antenna. The bandwidth of the realised gain of the active antenna can also be determined with this technique. The validity of the proposed technique is verified by the measurement of an active microstrip antenna.

Introduction: The active microstrip antenna in which an amplifier is integrated with a microstrip patch has recently received an increasing amount of attention [1, 2]. In addition to the advantages of reducing the losses in the feed circuits, this type of active antenna can be designed with higher realised gain and wider gain bandwidth compared to its passive counterpart, by matching the active circuit with the microstrip patch [3, 4]. However, it is impossible to measure the transducer power gain of the amplifier directly using the traditional two-port measurement technique, because the amplifier is an inseparable part of the active antenna. This Letter presents a novel measurement technique for determining the transducer power gain of an amplifier integrated in an active antenna.

Active antenna gain: For active antennas, owing to the integration of active devices with radiating elements, there is no standard gain definition available [5]. However, where a single RF input port is available, the realised gain of an active antenna can still be defined in the standard way; referring to Fig. 1 [6]

$$G_a(\theta, \phi) = 4\pi \frac{\textit{power density per unit solid angle in direction } \theta, \phi}{\textit{available power from source, } P_s} = G_T G_r(\theta, \phi) \qquad (1)$$

where G_T is the transducer power gain of the active circuit with the radiator as its load, defined as the ratio of the power absorbed by the radiating element P_a and the available power from the source P_s. It is only a function of frequency and independent of the direction θ, ϕ. G_r is the gain of the passive radiator from the standard gain definition.

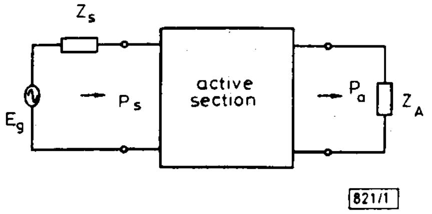

Fig. 1 *Transmitting active antenna configuration*

This gain definition of active antennas can result in a gain value substantially larger than the directivity of the passive radiator, because of the transducer power gain of the active circuit. The gain defined in this way would be a useful quantity for the system designer or builder who is interested in the transmission properties of the link containing the active antenna [5].

Measurement technique: The measurement setup used to test the designed transmitting active antennas is shown in Fig. 2. A standard gain antenna is connected at port 1 and the active antenna under test or a reference antenna at port 2 of an analyser. The distance L between the test antenna and the horn antenna satisfies the far field condition. The reference antenna is identical to the active antenna except that the active circuit in the active antenna is replaced by a passive lossless matching network in the reference antenna. With this measurement setup, the transducer power gain of the active circuit and the bandwidth of the total realised gain of the active antenna can be determined as follows.

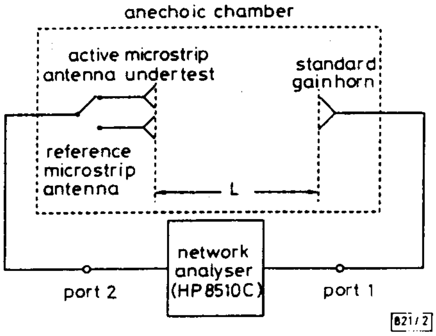

Fig. 2 *Measurement setup for the gain of an active antenna*

The transmission coefficient from the active antenna to the standard gain antenna is

$$(S_{12(a)})[\text{dB}] = 10 \log \left(\frac{G_a}{4\pi L^2} A_e \right) \qquad (2)$$

where A_e is the effective receiving area of the standard gain antenna. It is evident that if L is fixed and A_e remains constant within the measured frequency band, the frequency response of the gain G_a is exactly the same as that of $S_{12(a)}$ except for a shift of $-10 \log \{(1/(4\pi L^2)] \,.\, A_e\}$. Thus from this measurement the bandwidth of the realised gain G_a can be determined. To determine the transducer power gain of the active antenna, the reference antenna is measured. If the realised gain and return loss of the reference antenna are G_p and Γ_p, the transmission coefficient from the reference antenna to the standard gain horn is

$$(S_{12(p)})[\text{dB}] = 10 \log \left(\frac{G_p}{4\pi L^2} A_e \right) = 10 \log \left(\frac{(1 - |\Gamma_p|^2) G_r}{4\pi L^2} A_e \right) \qquad (3)$$

where G_r is the gain of the radiator and $(1-|\Gamma_p|^2)$ is the mismatch loss or the transducer power gain of the matching network of the reference antenna.

With the realised gain definition (eqn. 1) of the active antennas, eqn. 2 can be written as

$$(S_{12(a)})[\mathrm{dB}] = 10\log\left(\frac{G_T G_r}{4\pi L^2}A_e\right) \qquad (4)$$

As both the active and the reference antenna have the same radiator, from eqns. 3 and 4 the transducer power gain of the amplifier is obtained simply as

$$(G_T)[\mathrm{dB}] = (S_{12(a)})[\mathrm{dB}] - (S_{12(p)})[\mathrm{dB}] + 10\log(1-|\Gamma_p|^2) \qquad (5)$$

Because the same setup and environment are involved in the measurement of both antennas, this technique is a relative measurement, and therefore can guarantee a high accuracy.

Measured results: The validity of the proposed technique is verified by the comparison between measurement and calculation for several active antennas [6]. Here we show one example. The active antenna was designed for transmission with a two-stage amplifier configuration in a two-sided structure which is similar to the antenna structure reported in Reference 3. The details of this antenna can be found in Reference 6.

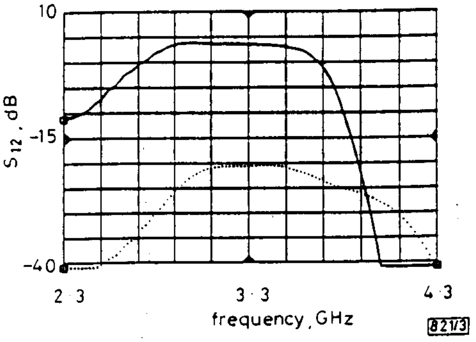

Fig. 3 *Measured transmission coefficients of two microstrip antennas with identical patches*

——— active antenna
······· reference antenna

The measured transmission coefficients of the active antenna together with those of the reference antenna are illustrated in Fig. 3. The reference microstrip antenna has a bandwidth of 14% (3·04–3·50 GHz) at the level of −10 dB return loss. It is evident that the active antenna can work over a very broad bandwidth. For the design bandwidth 3·1–3·5 GHz, the realised gain of the active antenna has a flatness of ±0·3 dB. For a criterion of flatness ±0·7 dB, the antenna can work in the frequency band 285–3·6 GHz, or 24·5% of the resonance frequency of the patch antenna. The measured transducer power gain realised by the amplifier of the active antenna is shown in Fig. 4 with a solid line. It has a mean value of 24 dB in the design band. For comparison, the simulated result is also given in this Figure with a dotted line. The agreement is fairly good. The difference between the two curves is mainly due to the uncertainty of the S parameters of the transistors used in the amplifier.

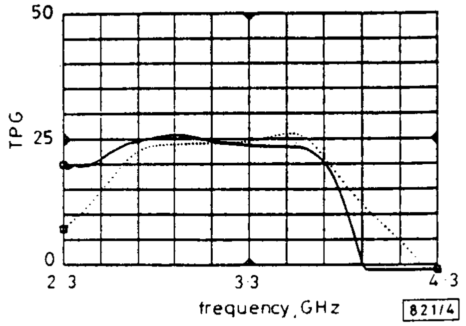

Fig. 4 *Transducer power gain of amplifier embedded in an active microstrip antenna*

——— measured
······· calculated

Conclusion: A novel technique has been proposed for the measurement of the transducer power gain of an amplifier in an active microstrip antenna. The bandwidth of the realised gain of the active antenna can also be determined with this technique. The measurement results of an active antenna show the validity of the proposed technique. This technique has also been applied in the noise measurement of receiving active antennas which will be reported elsewhere.

19th July 1993

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ANTENNA PERFORMANCE ENHANCEMENT BY SLOTTED MICROSTRIP PATCHES

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Indexing terms: Antennas, Microstrip patches

Slotted microstrip patches fed by aperture coupling are proposed and studied for multifrequency operation. By removing parts of the patch conductor, a single-frequency antenna can operate at multiple frequencies. An example is given to demonstrate its dual-frequency operation and performance.

Introduction: Although microstrip antennas have many attractive structural features, disadvantages in electrical performance, such as narrow bandwidth and poor polarisation, have prevented their use in some applications. Conventional microstrip radiators in the form of rectangular and circular patches, or rings, resonate at a single frequency and operate satisfactorily only over a narrow band. The bandwidth can, however, be increased by using coupled resonators, such as coplanar parasitic elements or stacked structures. Dual frequency operation is also possible by increasing the coupling coefficient between the resonators, i.e. decreasing their spacing. However, the coplanar configuration increases the antenna size and stacked structures are thick and heavy.

For dual frequency operation, in this Letter a better solution is proposed by using a slotted patch. The patch is fed by a microstrip line through a coupling aperture in the ground plane. Its performance is investigated using a spectral domain moment method that determines its input impedance and radiation characteristics. Multifrequency operation is also possible, which can be achieved by introducing additional slots on the patch.