CAVITY INDUCED POLARISATION SWITCHING IN A SLOT-LOOP ACTIVE ANTENNA

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ABSTRACT

New features of a cavity backed active slot-loop antenna are discussed in this paper. By using a high Q cavity, 35 dBc phase noise level reduction @ 200 KHz from the carrier has been achieved. Once in resonance, the established TE_{110} cavity fields rotate the principle E-plane of the slot-loop antenna through 90^{o}. This results in an exchange of E- and H-plane locations in radiation pattern together with reduced cross-polarisation levels. Thus the presence of the cavity tuned into and out of resonance allows the antenna to have its polarisation properties orthogonally switched.

INTRODUCTION

Slotline antennas have the advantage of easy integration with two or three-terminal active devices when compared with microstrip based planar antennas since via-holes are not required. This is particularly attractive in planar monolithic and quasioptical technologies which require active antenna arrays in order to partially combine high frequency energy from many devices together.

A simple and compact FET active slot loop antenna was proposed recently [1] and was the subject of electromagnetic study in [2]. Here, the three terminal device was conveniently integrated into the slot-loop. However, when compared with a microstrip patch antenna, two drawbacks for an active slot loop antenna were observed, namely, 1) poor phase noise performance due to lower overall external quality factor and 2) bi-directional radiation characteristics which reduces overall antenna gain. The second drawback was addressed by Moyer and York [3] using a slot dipole backed with a non-resonant cavity. In the work presented here, rather than using a non-resonant cavity, a tuneable resonant cavity was used to back an active slot loop antenna. The resulting structures obtained showed novel behavioural characteristics with respect to polarisation rotation as well as phase noise improvement. These effects are reported in this paper.

The cavity, once in resonant with the active slot-loop antenna, not only reduces the phase noise (35 dBc reduction @ 200 KHz offset has been achieved), also the cross-polarisation level of the radiation pattern is considerably reduced. Furthermore, our findings show that the radiation pattern of the antenna in resonant mode is quite different from that in off-resonant mode. This means by tuning the antenna cavity into and out off resonance, we can switch the antenna, from one polarisation orientation to another.

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CAVITY ATTACHED SLOT-LOOP ANTENNA

Fig. 1 shows the configuration of a rectangular slot loop antenna mounted over a metal cavity. The circuit, with a total size of L=102 mm and W=68 mm, is built on Duroid 5880 substrate, dielectric constant 2.2 and thickness 0.254 mm. An ATF26884 FET is used as the active device. A square slot-loop antenna designed to operate at around 5.5 GHz, has Ls=18.1 mm and Ws=0.6 mm, a small gap Gs=0.1 mm is used to permit separate gate and drain of device for dc bias. The dimensions of the cavity are chosen to resonate around the same frequency as the antenna, were A=40 mm, T=14 mm, L1=L2=24.95 mm and L3=24 mm. Dimension B is allowed to vary by means of a sliding block arrangement. Two different depth cavities, one D=5 mm and the other D=40 mm with theoretical unloaded Q factors of 4300 and 14000 respectively, are used to examine the effects of different cavity quality factors on the noise level improvement.

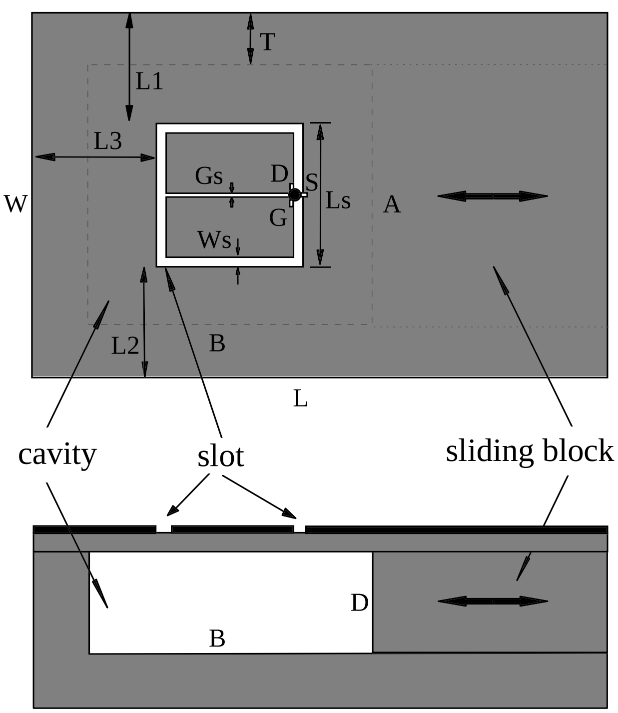


Fig. 1 Configuration of a cavity attached slot loop antenna

The resonant cavity can be attached to the top or back side of the circuit substrate to improve the total quality factor of the circuit. In the case where a cavity is attached to the top side of the slot loop antenna, the slotline metal sheet will be part of the resonant cavity. Dc bias needs to be arranged for the FET embedded in the cavity. Alternatively, the cavity can be attached to the back side of the slot antenna in which case the dc bias can be easily applied to the top circuit.

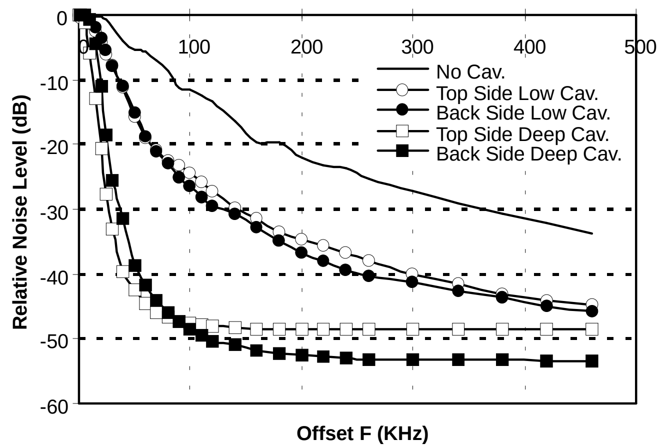


Fig. 2 Spectrum of the slot loop antenna under different cavity conditions (RBW=10 KHz, VBW=30 Hz and SPAN=1 MHz)

Fig. 2 shows the frequency spectrum envelope for the antenna under different cavity conditions. In the experiments, a constant 2.5 volts drain bias voltage was used. It can be seen from the figure that the cavity presence can greatly enhance the spectral purity of the slot loop antenna. For a given cavity, the noise performance achieved by a cavity attached to the back side of the slot loop is almost as good as that to the top side. The typical phase noise improvement obtained at a 200 KHz offset frequency are 14 to 17 dB for the shallow cavity and 28-35 dB for the deep cavity.

It has been shown in reference [4] and the Leeson's equation [5] that within the usable bandwidth of the cavity $f_0/2Q$, the Phase Noise Reduction can be approximated by

$$PNR \approx 20 \cdot log_{10}\left(\frac{Q_{osc1}}{Q_{osc}}\right) \qquad \textbf{(1)}$$

where Q_{osc} and Q_{osc1} are the loaded Q of the oscillator without and with cavity. The Q_{osc} of the active slot loop without cavity was measured to be around 12 using an injection locking technique [6]. From equation (1) the Q of the antenna with a shallow and a deep cavity are around 75 and 425 giving 16 dB and 31 dB PNR respectively. These results are in agreement with those measured.

POLARISATION SWAPPING

Fig. 3 and 4 show the radiation patterns of the slot-loop antenna without any backing cavity and with a non-resonant cavity. Same normalisation value for power level is used for comparison. It can be seen that the radiation power levels in Fig. 4 were increased by approximately 1 dB due to cavity reflection but the radiation patterns were similar. However, once the cavity is tuned to the working frequency of the active antenna, a resonant field is established inside the cavity. Consider Fig. 5, first the principle E-plane vector

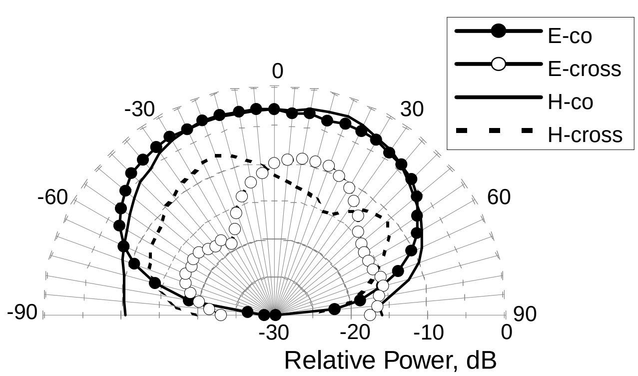


Fig. 3 Radiation patterns of slot-loop antenna without cavity backing

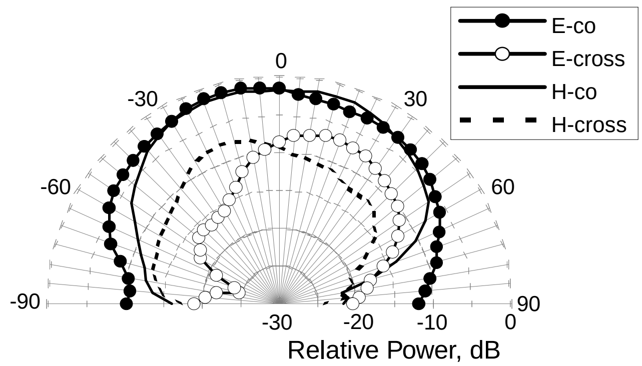


Fig. 4 Radiation patterns of slot-loop antenna with backing cavity not in resonance

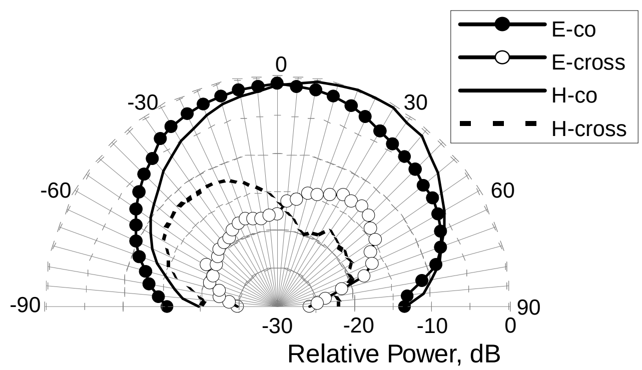


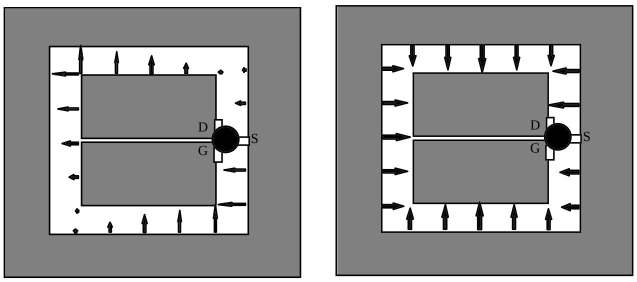
Fig. 5 Radiation patterns of slot-loop antenna with backing cavity in resonance

is rotated through 90 degrees (the E-plane in Fig. 3 and 4 becomes H-plane in Fig. 5, and the H-plane now becomes the E-plane, Table 1). Second, the cross-polarisation levels in Fig. 5 are considerably lower(about 6 dB) than those in Fig. 3 and 4. The reason for these happening is that the TE_{110} resonant field distribution established inside the cavity when in resonant is different from the sine wave field pattern of a non-resonant cavity backed or standard slot-loop antenna, see Fig. 6. Due to the symmetric nature of the resonant fields

Table 1 Radiation pattern relation between cavity in and off resonance

off resonance		in resonance
E-co	↔	H-cross
E-cross	↔	H-co
H-co	↔	E-cross
H-cross	↔	E-co

shown in Fig. 6(b), the electric fields generated by the upper and lower arms of the slot-loop are self-cancelling, therefore the vertical plane in Fig. 6(b) becomes the H-plane. However, due to the existence of the active device in the right arm of the slot loop, the electric fields radiated from the left and right slot



(a)
off resonance
(sinusoidal)

(b)
in resonance
(TE_{110})

Fig. 6 Electric field distribution of the slot-loop antenna in different operation modes

arms will not completely cancel, therefore the horizontal plane in Fig. 6(b) becomes the E-plane. This also explains why the antenna in resonant mode has lower cross polarisation levels. Also it can be seen in Fig. 5 that the radiated power levels in Fig. 5 are approximately 1.2 dB higher than those with a non-resonant cavity shown in Fig. 4.

CONCLUSIONS

The new findings described above show that by using a high Q resonant cavity, the phase noise level of an active slot-loop antenna can be considerably reduced, and the E and H-plane polarisation orientation of the antenna can be swapped by tuning the cavity into and out off the resonance condition. In addition, the cross-polarisation levels of the active antenna can be reduced.

ACKNOWLEDGEMENTS

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