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Reprinted from
IEEE Microwave and Guided Wave Letters, Vol. 1, No. 11, November 1991

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A Microstrip Patch Antenna with Coplanar Feed Line

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Abstract—An experimental investigation of a microstrip patch antenna with a coplanar feed line is presented. The coupling from the coplanar line to the patch is accomplished via a slot in the ground plane to which the coplanar line is connected either inductively or capacitively. The input return loss can easily be adjusted via the slot length. Additional frequency tuning is possible by switching between inductive and capacitive coupling.

I. INTRODUCTION

MICROSTRIP antennas have found widespread applications for microwave as well as millimeter wave systems. On the other hand, for components including active devices, especially MMICs, coplanar line is gaining an increasing interest. Coplanar line allows the realization of series as well as shunt connections on one side of the planar substrate avoiding via hole connections. Furthermore, the substrate can be relatively thick. This fact, on the other hand, matches well with good efficiency and improved bandwidth of microstrip antennas integrated on the same substrate.

A first but less successful effort realizing coplanar antennas is described in [1], and in [2], a dielectric resonator antenna is fed with a coplanar line.

II. COPLANAR FED PATCH ANTENNA

To combine the advantages of coplanar line and microstrip patch antennas, two antenna configurations as shown in Fig. 1 were fabricated and investigated experimentally. A patch resonator is placed on one side of the substrate, while a slot is arranged opposite to the patch in the ground plane. The slot then is fed with a coplanar line. The inner conductor of the coplanar line may either be connected directly across the slot forming an inductive type of feeding (Fig. 1(a)), or it may be coupled to the slot in a capacitive way (Fig. 1(b)). Such a coplanar fed slot is used, too, in the design of a coplanar FET oscillator [3].

The antenna arrangement presented here is partly similar to that described in [4] where a slot in the ground plane is fed via a microstrip line on an additional substrate layer; besides the use of coplanar line, however, our structure avoids the additional substrate layer.

The patch was designed using transmission line calculations [5] to operate—without the slot in the ground plane—in the range of 5 GHz. The slot, however, introduces an

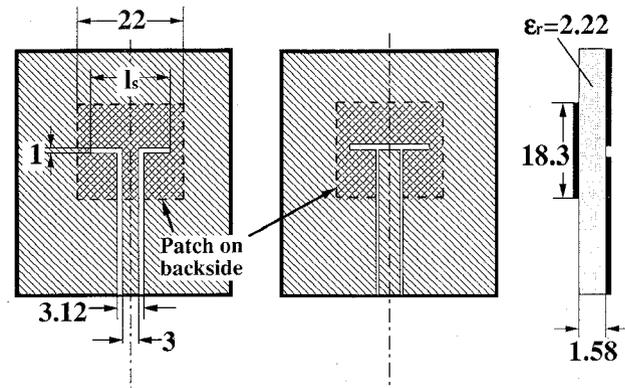


Fig. 1. Configuration of the coplanar fed microstrip patch antenna with inductive (a) and capacitive (b) coupling.

inductive component to the current in the ground plane, thus the frequency of operation is reduced. The width of the slot was chosen to be 1 mm.

As a first test, the input return loss of both structures was measured as a function of slot length. To this end, the slot length was reduced little by little soldering thin metal strips across the end portions of the slot. In both structures, a good match could be obtained, while the frequency was changed to some extent, too. The dependence of return loss and operating frequency on slot length is plotted in Figs. 2 and 3 for the two feeding structures. In the case of the inductive coupling, the return loss depends strongly on the slot width, while in the capacitive coupled arrangement, the return loss is low over a wide range of slot widths. The antenna bandwidth (10 dB return loss) was around 3.5% for the inductive coupling, but only 2.8% for the capacitive coupling.

Regarding Figs. 2 and 3, it can be seen that an acceptable return loss for both structures can be achieved at the same slot length but at different frequencies. This fact raised the idea to tune or switch the frequency of operation using a varactor diode or a PIN diode, respectively, to modify the coupling. To test this, a modified structure was used (Fig. 4), and the effect of a PIN diode was simulated by an open circuit or a thin wire soldered from the end of the coplanar center conductor to the opposite side of the slot. The return loss versus frequency for both cases is plotted in Fig. 4. A frequency shift of 370 MHz is achieved in this way, maintaining a return loss of better than -20 dB at the center frequencies.

Both structures were tested, too, in a simple, provisional antenna range. The H -plane radiation patterns are shown in Fig. 5. The capacitive coupling shows a 3-dB beamwidth of

Manuscript received July 1, 1991.

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IEEE Log Number 9103573.

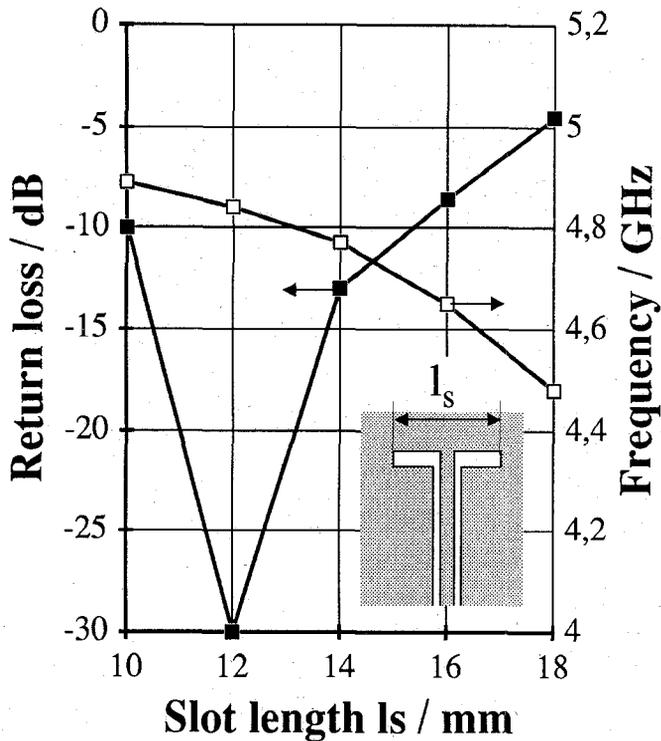


Fig. 2. Return loss and resonant frequency of the antenna with inductively coupled slot.

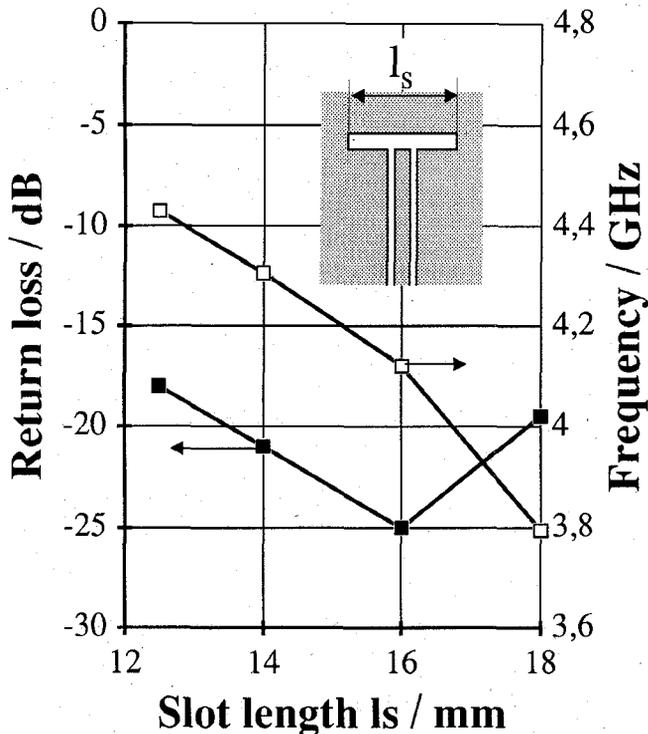


Fig. 3. Return loss and resonant frequency of the antenna with capacitively coupled slot.

80° and a backward radiation level 9.5 dB below the main beam. For the inductive coupling, these data amount to 70° and 10 dB, respectively. It should be noted, however, that in the latter case the frequency was about 8% higher.

In the *E*-plane, the 3-dB beam width (for the inductive

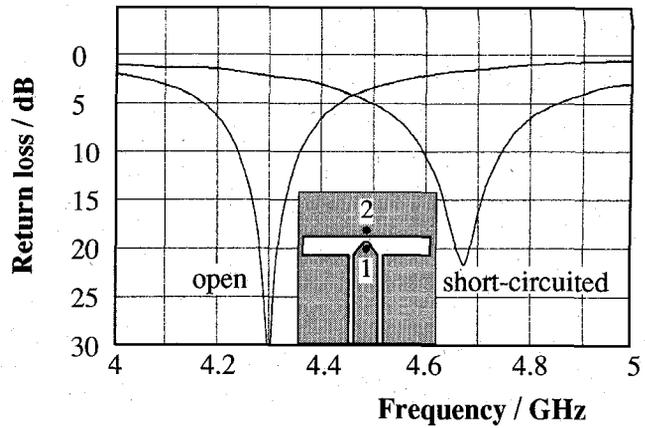


Fig. 4. Return loss versus frequency of the patch antenna simulating PIN diode switching between inductive and capacitive coupling (open circuit or short circuit between points 1 and 2). Slot length is 13.3 mm.

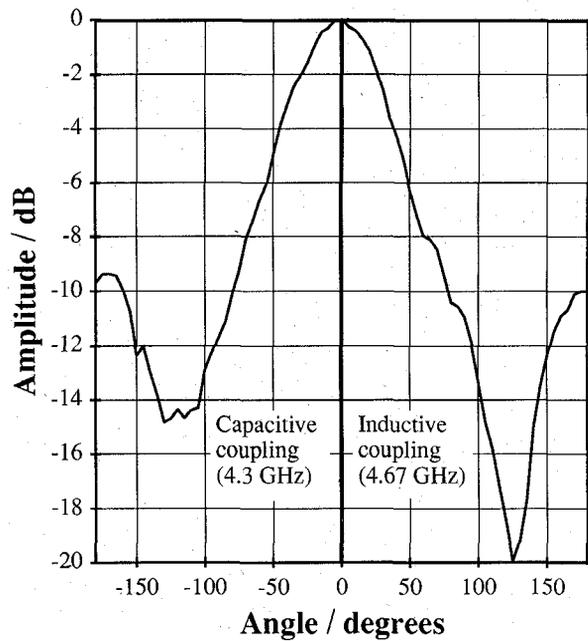


Fig. 5. *H*-plane radiation pattern for patch antenna with capacitive (left side) and inductive (right side) slot coupling.

coupling) was measured to 67°. All diagrams are relatively broad at low elevation angles; this is due to the small substrate width of only 50 mm [6].

III. CONCLUSION

A new concept for feeding a microstrip patch antenna has been presented. Good impedance match was found with different types of coupling, and a frequency shift can be achieved switching between capacitive and inductive coupling. As it is known from other slot coupled patches [4], some radiation is found on the backside of the structure; as long as the slot is not in resonance, however, this backward radiation can be kept relatively small.

Further investigations have to be done concerning the influence of slot width on frequency, impedance match, bandwidth and tunability.

REFERENCES

- [1] J. W. Greiser, "Coplanar stripline antennas," *Microwave J.*, pp. 47-49, Oct. 1976.
 - [2] R. A. Kranenburg *et al.*, "Coplanar waveguide excitation of dielectric resonator antennas," *Trans. Antennas Propagat.*, vol. 39, pp. 119-122, Jan. 1991.
 - [3] B. Roth and A. Beyer, "Planar slotline millimeter wave resonator with coplanar coupling," in *19th European Microwave Conf.*, London, England, 1989, pp. 507-512.
 - [4] P. L. Sullivan and D. H. Schaubert, "Analysis of an aperture coupled microstrip antenna," *IEEE Trans. Antennas Propagat.*, vol. AP-34, pp. 977-984, Aug. 1986.
 - [5] H. Kirschning and R. H. Jansen, "Accurate model for effective dielectric constant of microstrips with validity up to millimeter-wave frequencies," *Electron. Lett.*, vol. 18, pp. 272-273, 1982.
 - [6] A. K. Bhattacharyya, "Effects of ground plane and dielectric truncations on the efficiency of a printed structure," *IEEE Trans. Antennas Propagat.*, vol. 39, pp. 303-308, 1991.
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