A bidirectional dual-frequency antenna configuration

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Abstract

A compact arrangement incorporating - on opposite sides of a multilayer structure - two planar antennas or both a planar antenna and a transition from rectangular waveguide to microstrip line is presented. The elements on the different sides of a common ground plane may be designed either for the same or for different frequencies, thus including diplexing functions into the arrangement. Simulated and measured transmission performance and the radiation patterns of the device are given. The theoretical analysis is based on a modified spectral domain procedure. The design of a simple mixer taking advantage of the structure is demonstrated, and some other possibilities for application are given.

Introduction

Planar circuits have found widespread applications in the microwave and mm-wave region. In contrast to conventional planar structures, additional degrees of freedom concerning the design of microwave and mm-wave components can be obtained by the use of multilayer structures. In this contribution, a three layer structure according to Fig. 1 is presented. The structure in principle is a combination of two well known feeding techniques for patch antennas, that is the electromagnetic coupled (EMC-) dipole, e.g. [1], and the concept of aperture coupling [2]. The latter was used here to realize a planar antenna element or, alternatively, the integration of a transition from rectangular waveguide to the planar circuit as it was proposed by the authors in [3], [4]. A number of applications can take advantage of the device, some examples are given in Fig. 2. In this contribution, the possibily of an integrated mixer design according to Fig. 2a and Fig. 5 is demonstrated. An EMC patch antenna acts as the receiving element for the RF-signal, while the LO-signal is guided to the circuit using a metal waveguide connected to the back side of the planar structure. Due to the shielding ground plane and the individual matching of the radiating elements, good isolation between the two signals can be achieved if the coupling slot, which causes some spurious radiation, is kept electrically small. To optimize isolation, aperture coupling through the slot should be used for the signal with the higher frequency.

Theoretical Description

For the theoretical calculation of the radiation pattern and the input impedance of the structure, a more general equivalent structure with lateral shieldings according to Fig. Ib was investigated using the spectral domain method [5]. Because of different lateral structures above and below the ground plane, however, the method has to be modified using a the procedure outlined in [6]. Introducing magnetic surface currents in the slot region allows for replacing the slot by a perfectly conducting plane, thus simplifying the analysis by creating two separate structures above and below the common ground plane. With this general formulation of the problem, both open and shielded structures as well as combinations of both can be treated, thus a great flexibility is achieved. For open structures, however, the effect of the lateral shieldings concerning surface waves can be eliminated by introducing a small amount of dielectric losses ($\varepsilon_{ri} = \varepsilon_{ri}' - j\varepsilon_{ri}''$) in the layers of the corresponding region below and/or above the ground plane, thereby avoiding the need for evaluating the poles in the Green's functions (e.g. [7]). The input impedance of the structure, defined with respect to a reference plane on the microstrip line, can be extracted by assuming a current source J_s at an appropriate distance from the slot and evaluation of the corresponding standing wave pattern on the feedline.

Results

As a first test, a structure with a transition from microstrip line to rectangular waveguide and an EMC dipole according to Fig. la was investigated. Simulated and measured S-parameters of this structure are given in Fig. 3. The microstrip port is denoted as port 1, the waveguide port as port 2. It can be seen, that the power at about 11 GHz is transmitted to the waveguide, whereas it is radiated by the EMC dipole at about 8 GHz. Measured radiation patterns at these frequencies with a horn antenna connected at the waveguide port are given in Fig. 4. It can be seen, that the signals are received only from one corresponding direction and, in this configuration, are decoupled by at least - 12 dB. A similar arrangement was built and tested in combination with a planar mixer according to Fig. 5. The mixer was designed for 9.3 GHz RF-frequency and 10.3 GHz LO-frequency, resulting in an IF-Frequency of 1 GHz. Measured S-parameters and the radiation patterns of the optimized arrangement without mixer are given in Fig. 6 and 7, respectively. From this, the isolation at the LO-frequency can be estimated to be - 18 dB, whereas it is only about -8 dB for the RF-signal leaking to the LO-port, which usually is less critical. The conversion loss of this simple mixer configuration is plotted in Fig. 8 as a function of the LO-power. The whole arrangement was optimized to operate at 6 dBm LO-power, resulting in about 8.8 dB conversion loss with no external bias being applied.

To determine the RF power incident to the input of the mixer, an equivalent structure without mixer was used as a reference.

Conclusion

A multilayer circuit serving as a bidirectional dual frequency antenna has been designed and fabricated. The structure can be used as a signal combiner or a diplexer. In the modified set-up proposed here, one of the signals is coupled to the circuit via a transition from microstrip line to waveguide, while the other signal is received by an EMC antenna element. Calculated and measured results are presented, measured results agree well with the simulation. The concept of a simple, compact diode mixer taking advantage of the structure is presented, and measured results are given. Further possible applications are indicated, too. A number of additional features may be obtained by the combination of several elements in form of a two-sided antenna array.

References

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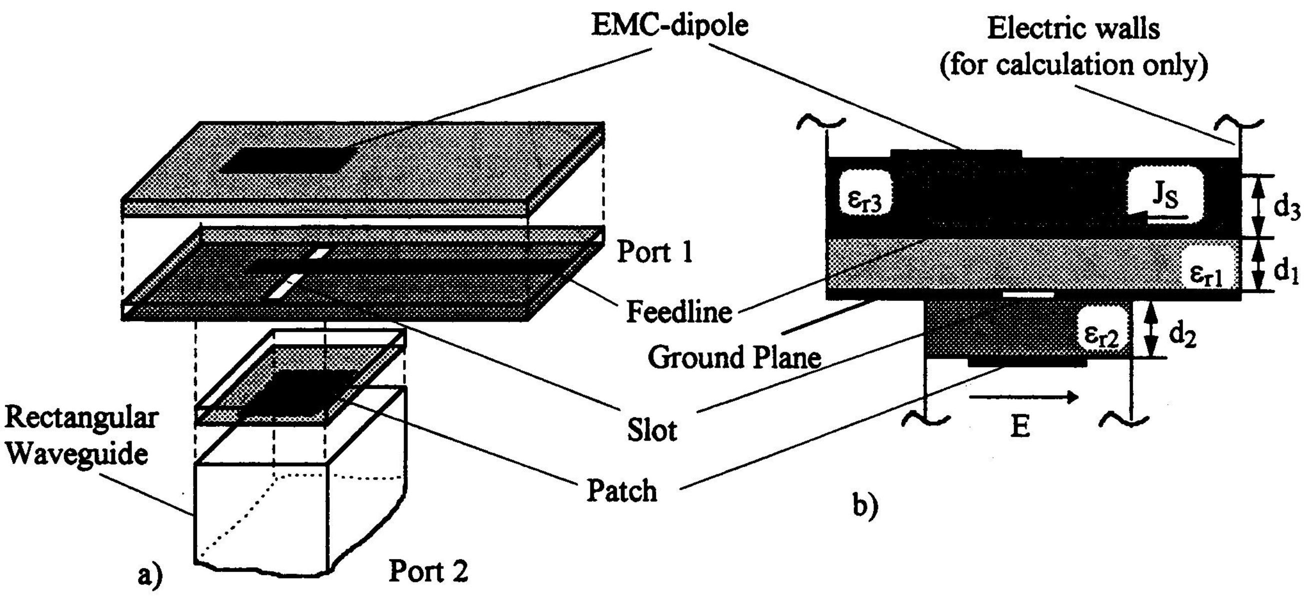

Fig. 1: Configuration of the multilayer structure a) Set-up. b) Equivalent structure for calculation.

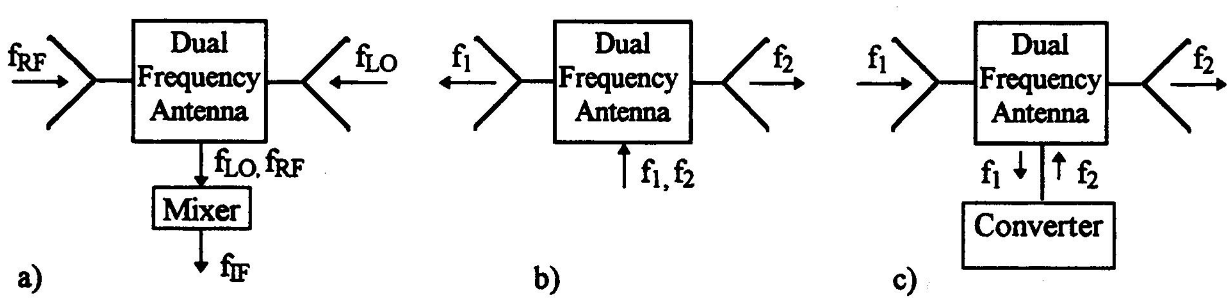

Fig. 2: Some possible applications of the device. (a) Mixer. (b) Diplexer. (c) Transponder, Multiplier.

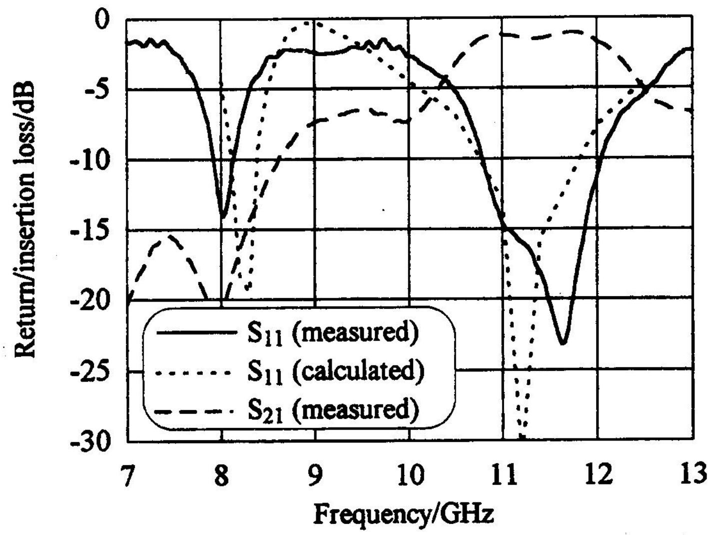

Fig. 3: Experimental and theoretical S-parameters (port1: microstrip; port2: waveguide; EMC dipole 12.4 x 1.0 mm; slot 1.0 x 5 mm; patch 7.0 x 12 mm; $\varepsilon_{r1} = \varepsilon_{r2} = \varepsilon_{r3}=2.33$; $d_1 = d_2 = 0.8$ mm; $d_3=1.57$ mm; $w_{MSL}=2.15$ mm (50Ω); waveguide 10.16 x 22.8 mm.

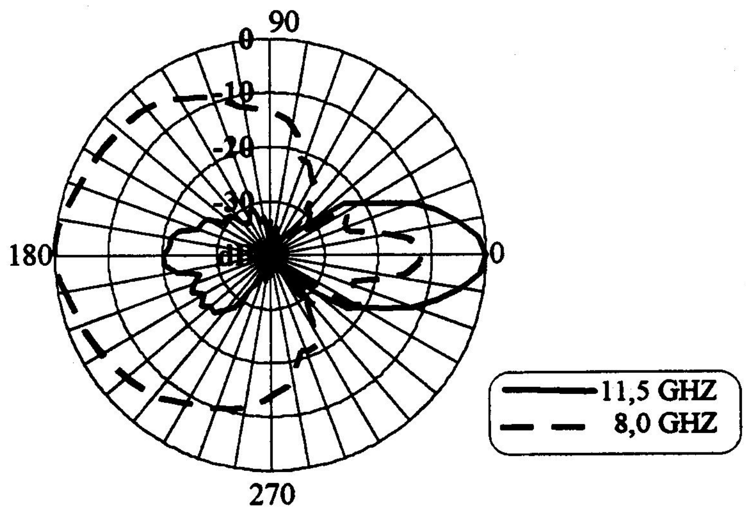

Fig. 4: Normalized H-plane radiation patterns at the two operating frequencies with a horn antenna connected to the waveguide (measured results). The horn antenna has a gain of approximately 20 dBi at both frequencies.

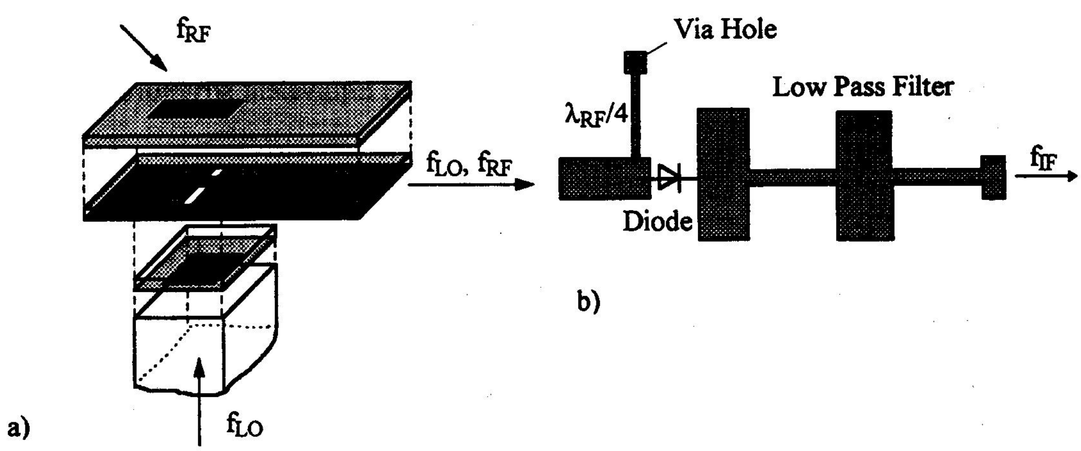

Fig. 5: Configuration of integrated antenna and mixer. (a) Set-up for combining RF- and LO-signal. (b) Schematic layout of a simple planar mixer in microstrip technique.

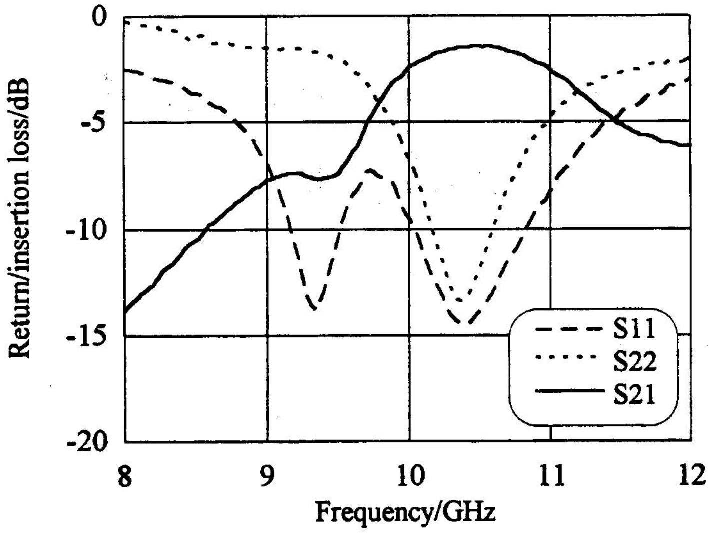

Fig. 6: Measured reflection and transmission of a configuration according to Fig. 5 for combining RF- and LO-signal at the input of a mixer (EMC dipole 9.3 x 8.0 mm; slot 0.7 x 4.9 mm; patch 7.7 x 15 mm; $\varepsilon_{r1} = \varepsilon_{r2} = \varepsilon_{r3}$=2.33; $d_1 = d_2$ = 0.8 mm; d_3=1.57 mm; w_{MSL}=2.15 mm (50 Ω); waveguide 10.16 x 22.8 mm)

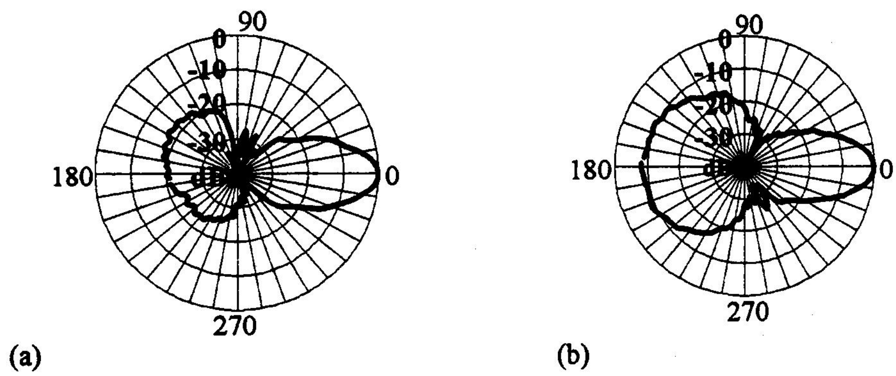

Fig. 7: Normalized radiation patterns in H-plane with a horn antenna connected to the waveguide. (a) f = 9.3 GHz. (b) f = 10.3 GHz. The horn antenna has a gain of approximately 20 dBi at both frequencies.

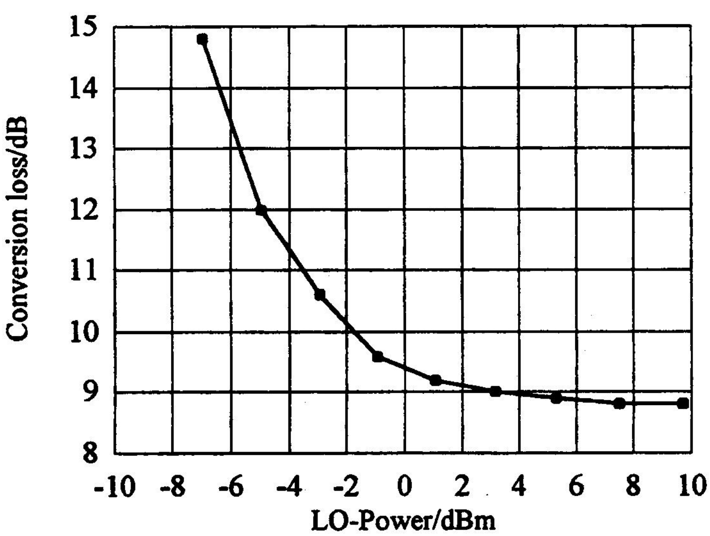

Fig. 8: Conversion loss of the mixer as a function of LO-power.