AN MMIC APERTURE–COUPLED MICROSTRIP ANTENNA IN THE 40GHz BAND

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1. Introduction

Recently, in millimeterwave and microwave applications, several concepts of monolithic antennas with which active solid–state devices and feed circuits are integrated have been reported [1]–[4]. This paper presents the fabrication and test results of an MMIC aperture–coupled microstrip antenna (MSA) integrated with a mixer and an amplifier. The characteristics of the antenna radiator were evaluated separately and a good radiation efficiency of 89% was obtained in the 40GHz band.

2. Configuration

Fig.1 shows the photographs of a fabricated aperture–coupled MSA with GaAs monolithic circuits, a mixer with a conversion loss of 9.5dB [5] and an amplifier with a gain of 9dB [6]. Fig.2 shows the configuration of the aperture–coupled MSA [7]–[9]. The coupling between a feed line and a radiating element is accomplished by an aperture in the ground plane. In this case, quartz (dielectric permittivity ε_r=3.8) and GaAs (ε_r=12.9) are used for the substrates of the radiating element and the feed circuit, respectively.

The major advantage of this configuration is that the reverse side of the antenna radiator is used for the active and feed components. Another advantage is that the design matches the antenna substrate (low ε_r) to the electrical characteristics such as high radiation efficiency and wide bandwidth. In addition, the ground plane isolates feed circuits from radiating elements and results in reducing undesirable coupling [7], [9].

3. Input Impedance

The followings show the characteristics of the antenna radiator exclusive of GaAs MMIC circuits. Fig.3 shows the measured input impedance of the antenna radiator for various open–stub lengths as a function of frequency in a Smith chart. The measurements were made with an HP–8510B network analyzer. In this figure, when the stub length is approximately 1/4 λg, where λg is the wave–length in the dielectric substrate, the locus of the impedance rotates around the real axis and an impedance match is achieved.

The measured resonant frequency versus the slot length is plotted in Fig.4. It is seen from this figure that resonant frequency decreases with increasing the slot length [8]. Also plotted in Fig.4 is the input resistance at resonance versus the slot length. As the slot length is reduced the input resistance decreases. From this figure, the slot length can be determined to achieve a matching condition. For comparison the calculated resonant frequency of circular MSA without slot based on the cavity model is plotted in Fig.4. From this figure, the resonant frequency of the antenna is determined primarily by the patch length, but it is affected slightly by the slot length.

The calculated and measured bandwidth of this antenna are shown in Fig.5. Calculated values are obtained from the mode expansion analysis in circular MSA [10]. The measured bandwidths (BW) that satisfy VSWR$\leqq$1.5, 2, and 3 are obtained 1.5%, 3%, and 5.5%, respectively. Measured values are in good agreement with calculated values. It is clear from this figure that equal bandwidth is obtained compared to circular MSA without slot.

4. Efficiency

Fig.6 shows the measured radiation patterns in the (a) E–plane and (b) H–plane. Cross–polarization is below 15dB in the E–plane and H–plane. The front–to–back ratio is consistently below 16dB. In the calculation, the finite ground plane is taken into consideration. Calculated values are in relatively good agreement with measured values, with some distortions being due to diffractions from antenna fixture. The measured gain of this antenna is 6dB at boresite including loss of 1.5dB of the feed line. The directive gain of this calculated pattern is 8dBi. Therefore, the antenna radiation efficiency of approximately 89% (directive gain minus measured gain) is obtained by excluding the above loss.

5. Conclusion

An MMIC aperture–coupled microstrip antenna integrated with a mixer and an amplifier has been developed and its high efficient characteristics have been verified in the 40GHz band. The antenna has reasonable gain, bandwidth, low cross–polarization and back–radiation.

References

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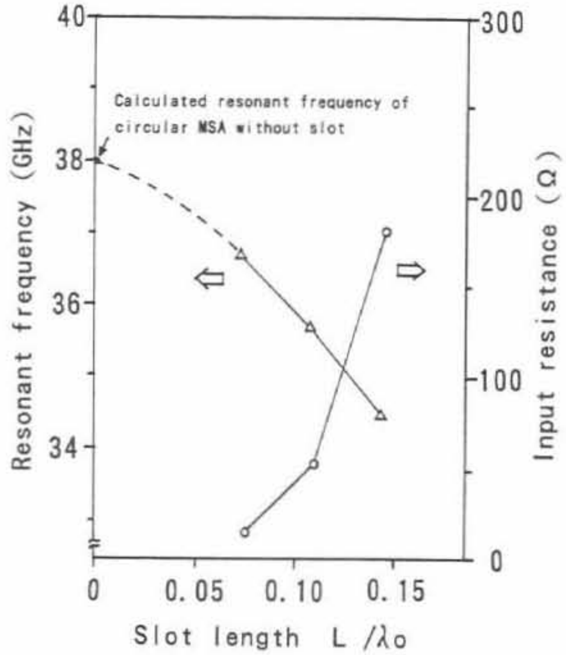


Fig.4. Measured resonant frequency and input resistance at resonance versus slot length. $a=0.132\lambda o, W=0.024\lambda o$.

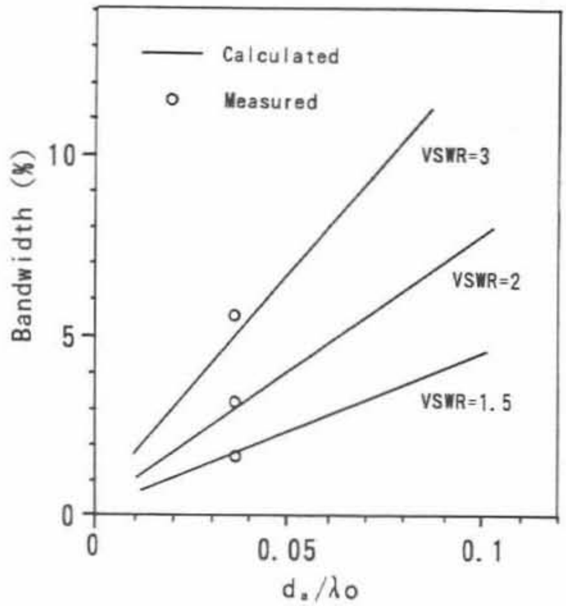
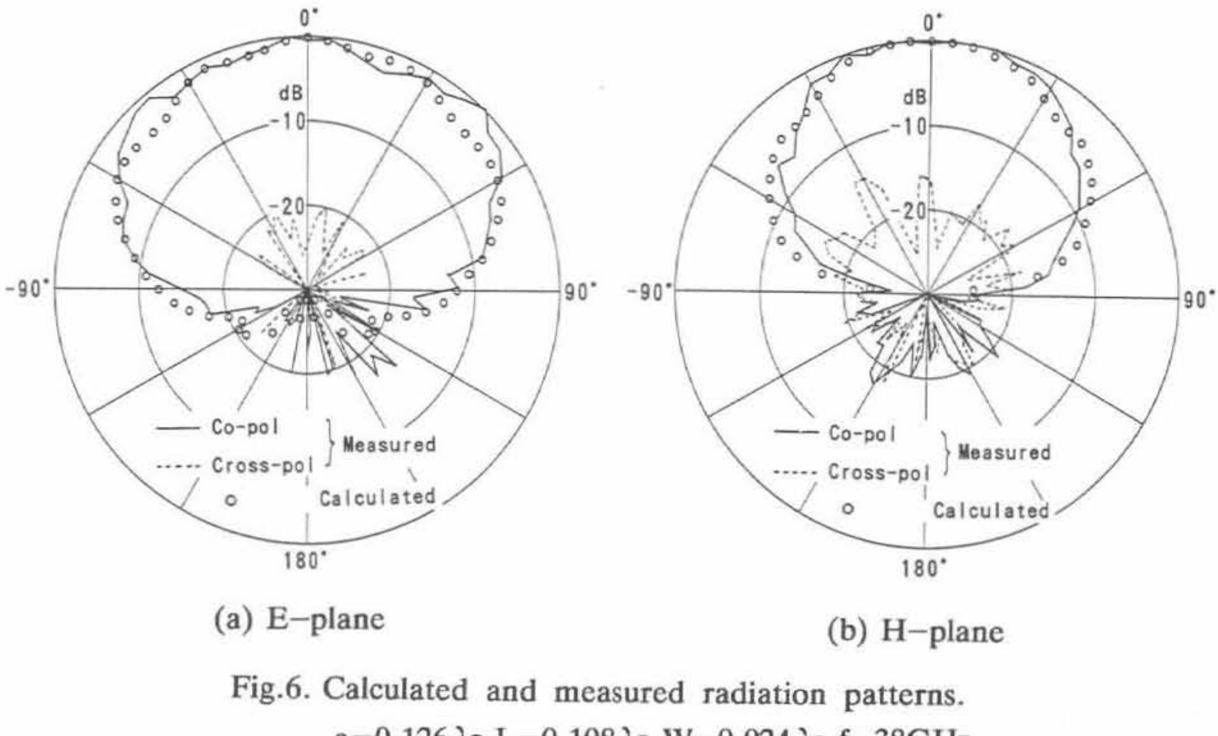


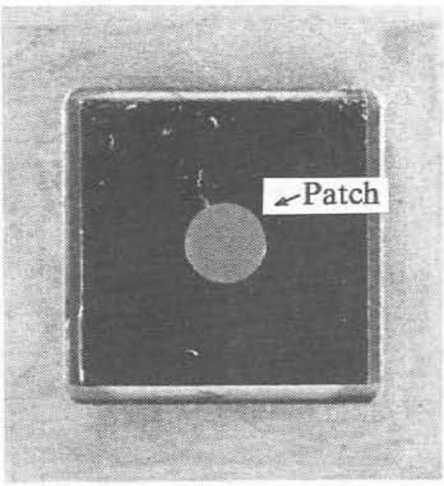
Fig.5. Calculated and measured bandwidth versus thickness of quartz substrate.



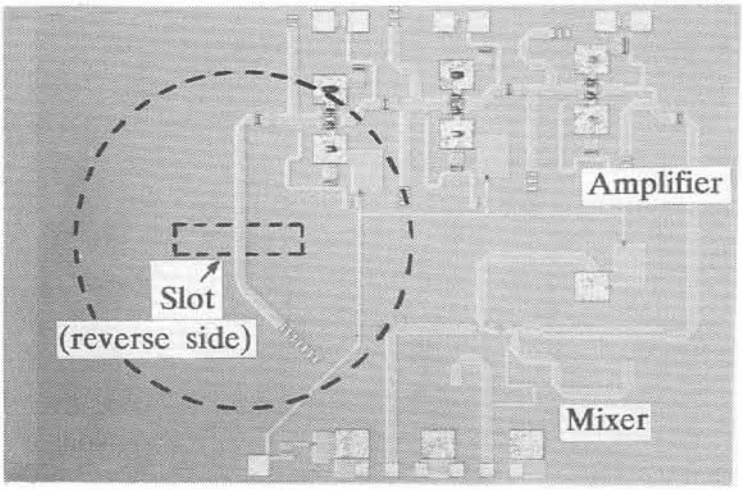
(a) E−plane

(b) H−plane

Fig.6. Calculated and measured radiation patterns. $a=0.126\lambda o, L=0.108\lambda o, W=0.024\lambda o, f=38GHz$.

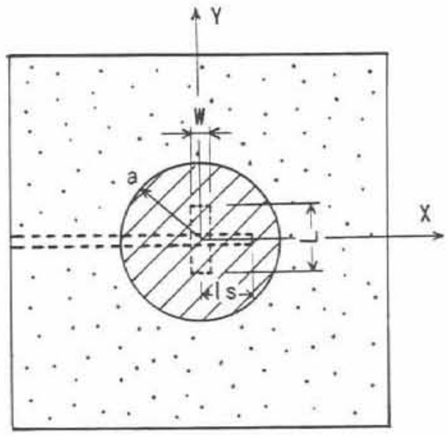


(a) Circular microstrip antenna.

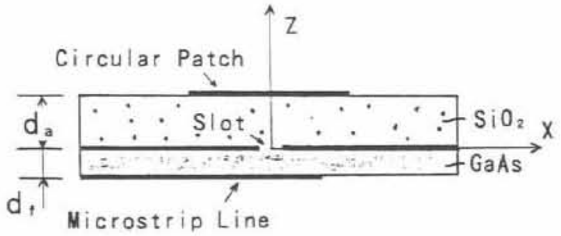


(b) Mixer and amplifier.
(chip size is 3.3mm×5mm)

Fig.1. Photograph of a fabricated aperture-coupled microstrip antenna and GaAs monolithic circuits.



(a) Top view.



(b) Cross-sectional view.

Fig.2. Configuration of an aperture-coupled microstrip antenna.

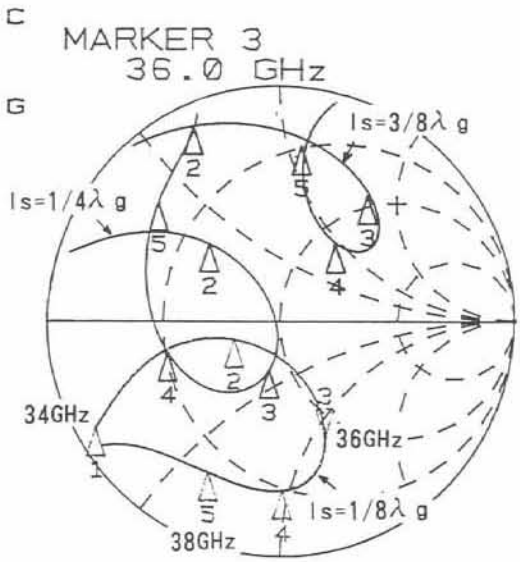


Fig.3. Measured input impedance as a function of the open-stub length. $a=0.132\lambda o, L=0.108\lambda o, W=0.024\lambda o$.