

Effect of Accretion Sand on Radiation Properties of Microstrip Antenna at Microwave Frequencies

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Abstract
Radiation properties of microstrip antenna embedded under the sand bed of grain size (120-180) microns are observed experimentally at 10 GHz frequency. Effect of surface waves on radiation properties is observed by changing the thickness of sand over the radiator.
Keywords: Sand, Microstrip Antenna, Microwaves

1. Introduction

A microstrip antenna is made with a thin sheet of low-loss insulating material, called the dielectric substrate (Pozar 1992). It is completely covered with metal on one side, called the ground plane and partly metalized on the other side, where the antenna shapes are printed.

Microstrip antenna are finding extensive applications in different fields due to their light weight, small size and better aerodynamic properties (Bahl 1980). In the present communication , a rectangular microstrip antenna is initially covered by a thin sand bed($=\frac{\lambda_d}{4}$) containing very fine sand particles. The grain size of these particles is kept fixed between 120-180 microns. This problem is most often common in stormy places and especially in the sand desert. Though, the effect due to such accretion of sand is not remarkable for electromagnetic waves in the region of relatively low frequencies, but the effect in the microwave region cannot be neglected.

By changing the thickness of the sand bed over the microstrip radiator, different radiation properties are observed experimentally at 10 GHz. Some theoretical results are also presented for comparison and for better understanding.

2. Experimental Details

A rectangular microstrip antenna on glass epoxy substrate ($\varepsilon_r = 4.39$ and loss tangent ≈ 0.01) is designed to operate at 10GHz frequency as shown in figure (1). Length of the radiator is (L=1.44cm), width (W=0.716cm) and thickness of substrate (h=0.16cm). During fabrication process, the possible human error can take place in the measurement of L and W. With the present structure we observed the resonant frequency equal to 9.74GHz. The microstrip radiator was fed by inset coaxial connector. The distance between edge of the radiator and feed point is kept constant (0.26cm) to match

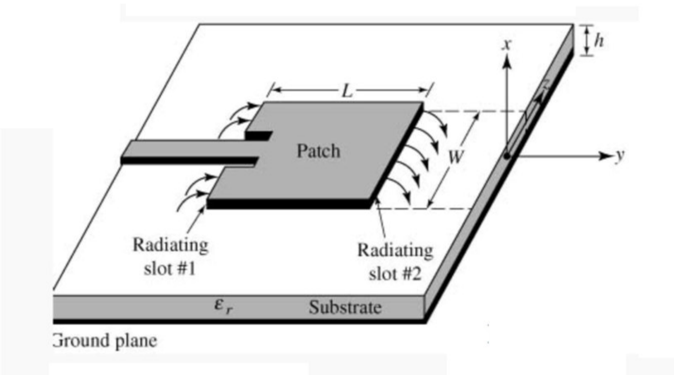

Figure 1. Geometry of rectangular microstrip antenna

the input impedance of the coaxial connector (50Ω) which is used for feeding purpose. With such a radiator, different radiation properties are observed in free space as well as in the presence of different thicknesses of sand layer over a rectangular microstrip antenna.

3-Radiation Patterns of Sand Embedded Microstrip Antenna

Radiation pattern of an antenna is a representation of radiation characteristics as a function of azimuthally angle

φ and elevation angle θ with a constant radial distance between the transmitter and the receiver (Balanis 1982). On keeping the receiving horn antenna and transmitting microstrip antenna in far zone condition , the E-plane radiation are obtained in free space as well as in sand medium .The transmitting microstrip radiator was kept inside a cylindrical thermo cool box of radius 14cm and height 30cm.This box does not show any effect on the radiation intensity of an antenna and microwave energy passes through it unattenuated .The thickness of the sand covering the radiator can be adjusted precisely with an external arrangement. Measured results with this arrangement are presented in figure (2).

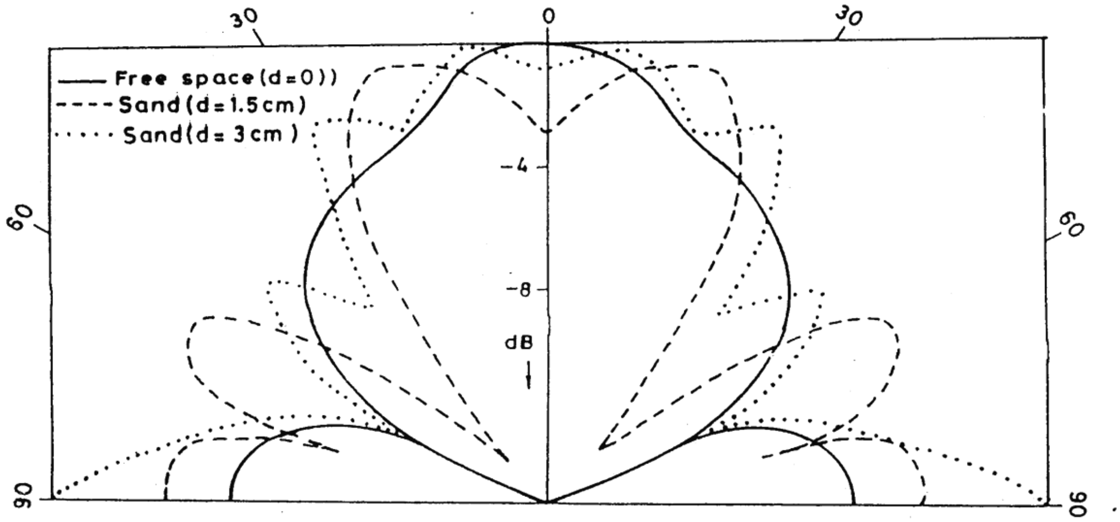

Figure 2.Radiation patterns

It is evident from the figure that on immersing our radiating system inside a sand medium, the direction as well as the magnitude of intensity changes considerably. In the present case radiated power distributes in different directions rather concentrating in a single direction $(\theta = 0)$.The presence of dielectric medium may lead the operation of a radiating element outside the band or it can increase the side lobe level or it can change the beam direction.

Present radiation patterns are completely different than the pattern obtained by Gupta (Gupta 1993) with both transmitter and receiver immersed inside the dielectric oil. In the present arrangement only the transmitter was immersed inside the sand sample while receiver was kept outside the dielectric media i.e. it was kept in free space. There are three possible reasons for such a changes in radiation patterns. Firstly, in the presence of a dielectric medium, the received power will be contributed by radiated waves as well as surface waves. The presence of surface waves can be visualized from figure(2).On increasing the thickness of the medium , the contribution of surface waves in the end fire direction increases and hence radiation pattern changes considerably. It can also be observed that on increasing the thickness of the sand layer over the radiator , 3dB beam width of the lobe in the end fire direction increases while 3dB beam width of the main lobe decreases significantly. Secondly, the dielectric medium is different than of free space and hence propagation constant changes which in turn changes the overall radiation pattern .Thirdly, the presence of sand layer over the radiator can also be treated as a dielectric cover which change the resonance frequency of the radiator . The shift in the resonance frequency may be larger than the range of bandwidth of the patch radiator .Any of these or all of these factors might be responsible for the drastic change in the radiation patterns of a radiator in the presence of a sand layer.

4-Voltage Standing Wave Ratio (VSWR)

In our measurements we have used a reflectometer to measure VSWR in place of VSWR meter. The experimental set-up is shown in figure (3), with this reflectometer , the reflection coefficient is measured which is related to the VSWR by the relation:

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \quad (1)$$

Where Γ is the reflection coefficient.

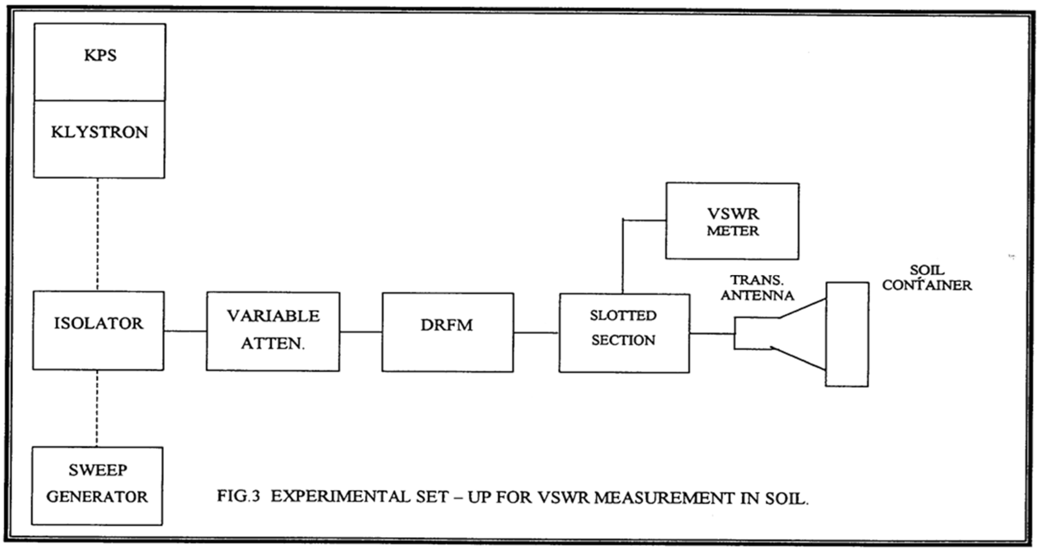

Figure 3. Experimental set-up

On increasing the thickness of sand layer, resonance frequency decreases but VSWR at resonance frequency increases. However every time, VSWR is minimum at the resonance frequency. Measured VSWR in the free space is greater than one which increases further on increasing the thickness of sand layer. This implies that more mismatched between transmission lines to antenna is taking place. The variation of VSWR with frequency is shown in figure (4). For three different thicknesses of sand layer over the radiator .On increasing the thickness of sand layer, return loss decreases .In the free space, theoretically calculated bandwidth of a rectangular microstrip antenna with same dimension is 9.8%. Experimentally observed bandwidth from table(1) is 7.5%. It is interesting to note from this table that the bandwidth increases considerably on increasing the thickness of sand layer. Further quality factor can also be related to VSWR by the relation:

$$Q = \frac{(S-1)}{(BW\sqrt{S})} \qquad (2)$$

Where S is VSWR and BW is the bandwidth.

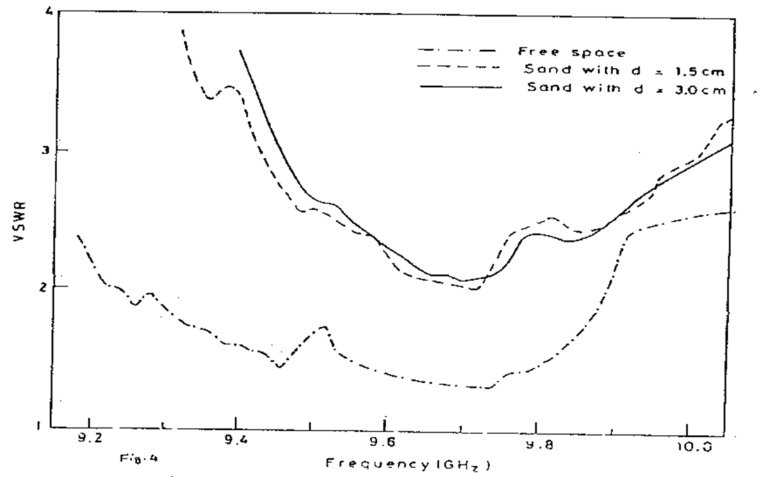

Figure 4. Variation of VSWR with frequency

It can be observed that quality factor reduces considerably on increasing the thickness of sand layer. All these parameters are systematically arranged in table(1).

Table 1.

Sample	Dielectric constant	Thickness (cm)	3dB of main lobe	Resonant Frequency (GHz)	VSWR	Return Loss(dB)	BW%	Quality Factor
Sand	3.405	O	96	9.74	1.32	11.2	7.51	284.22
		1.5	70	9.72	2.02	9.10	30	203.57
		3.0	28	9.7	2.06	9.2	39	156.27

5-Discussion and Conclusion

The radiation properties of a microstrip antenna embedded inside sand layer changes drastically on changing the thickness of sand layer over the radiator. When antenna is immersed in sand the bandwidth increases considerably. Dielectric constant of the sand medium is sufficiently high therefore energy stored in the medium is sufficiently large. Secondly sand medium is not a bound medium or a compact medium. When electromagnetic energy passes through it, every particle of sand medium becomes a source of scattering or reflection. This will increase the VSWR and hence bandwidth of the antenna.

On covering radiating patch by thin layers of sand sample. The splitting of radiation patterns in the different loops takes place which indicates that the radiated power gets re-distributed. On increasing the thickness of sand layer, contributions of surface waves in the end-fire direction increases resulting into increase in radiation in this direction.

A continuous increase in the thickness of sand layer causes more and more mismatch between the transmission line and the antenna which increase the value of reflection coefficient and hence VSWR.

All these studies reveal that the presence of the sand bed of fine particles changes the radiation properties of a microstrip antenna. By changing considerably, the environment around the antenna more information about the behavior of different antenna structures under different conditions can be gathered which may be fruitful for future designers.

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