Design of a Compact Microstrip Antenna using Capacitive Feed and Parasitic Patch for Ultra-Wideband Application

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Abstract- This paper proposes a novel approach to reduce size and increase the impedance bandwidth of microstrip UWB (Ultra-Wideband) antenna, when using a thick substrate, so that it can be used for WPAN application, especially for mobile and portable devices.The application of gap-coupled capacitive feeding mechanism for achieving UWB with microstrip antenna has also been proposed.. The proposed antenna is capable of operating over a bandwidth (6.4GHz-10.4GHz) as allocated by FCC (Federal Communications Commission), suited for an UWB (Ultra-Wideband) application. Although coaxial probe feed is one of the most popularly used feeding mechanism for thick substrates, but the inductance of the probe might create an impedance mismatch, which needs to be compensated by introducing a capacitive feed strip.

Index Terms- microstrip; Vector Network Analyzer (VNA); Capacitive; IE3D; Ultra-Wideband (UWB)

I. INTRODUCTION

Excitation of the microstrip antenna by a gap coupled coplanar capacitive feed strip appears to be a natural choice as the patch can be considered as an extension of the feed strip , and both can be simultaneously fabricated on the same plane, without much wastage of the substrate material. The gap -coupled capacitive feed strip requires a narrow gap width for efficient coupling of power. However ,a narrow gap size will limit the power handling capability of the antenna.

A thicker substrate is generally preferred in the design of a wideband microstrip antenna because not only it is mechanically strong ,but at the same time it provides increase radiated power ,reduce conductor loss , and improve bandwidth.

The capacitive feed strip used in the design of proposed antenna configuration works well with conventional geometries such as rectangular and triangular patches and provides good impedance bandwidth. It also reduces spurious radiations. Further, author have shown that by properly choosing the size of the feed strip and the separation distance between the feed strip and the driven patch, impedance bandwidth can be significantly improved up to 50%.

The antenna design was simulated, tested and characterized using Zeland's IE3D software and the measured results after fabrication of the antenna prototype were verified using vector network analyzer.

II. ANTENNA DESIGN

A. *Gap Coupled capacitive feed mechanism:*

The electromagnetically gap- coupled capacitive feed strip is represented by the equivalent circuit as shown in fig.1.This feeding mechanism provides compensation for the increased feed inductance. The effect of direct radiation from the open end of the microstrip line can be represented by a conductance across the shunt capacitor.

In such kind of antenna configuration, the radiation pattern becomes asymmetric due to capacitive loading. The radiation pattern can also be rotated electronically, by varying capacitive loading. This facility can be made use of to reduce the multipath fading in urban mobile communication when the antenna is mounted on a vehicle.

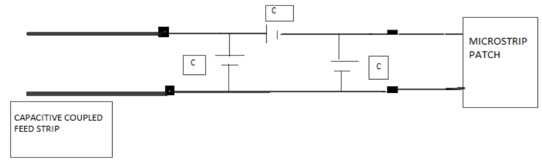

Figure 1: Equivalent Circuit Of a Gap Coupled Capacitive Feed Mechanism.

B. *Structural Details*

The key design parameters ,which can be optimized to maximize the bandwidth of the proposed antenna configuration, are the thickness of substrate(*h*),the distance between driven patch and the feed strip(*d*),and the capacitive feed strip dimension(*t* and *s*).In the following subsections, author examine the effects of these parameters on the antenna performance. All simulations are carried out using IE3D v.12.0, which is a method of moments (MoMs) based electromagnetic (EM) software. A parasitic patch is placed along with the radiating patch in the same plane to enhance the bandwidth more. The substrate (RT duroid) dielectric constant ‘ε_r’ is kept less to increase the fringing field at the patch periphery, and thus the radiated power. The stated antenna configuration is shown by fig.2.

A coplanar parasitic patch is used along the radiating edge of the driven patch so as to increase the bandwidth to 5.1 times to that of single rectangular patch. The distance between parasitic and the main patch is selected in such a way so that to provide better electromagnetic coupling. The basic principle underlying the operation of these antennas is the capacitive coupling between the driven patch and the parasitic patch. The loading effect produced by the parasitic patches lowers the quality factor, thereby increasing the impedance bandwidth.

The matching between impedance of capacitive feed strip and the antenna input impedance is shown by smith chart in fig.3.

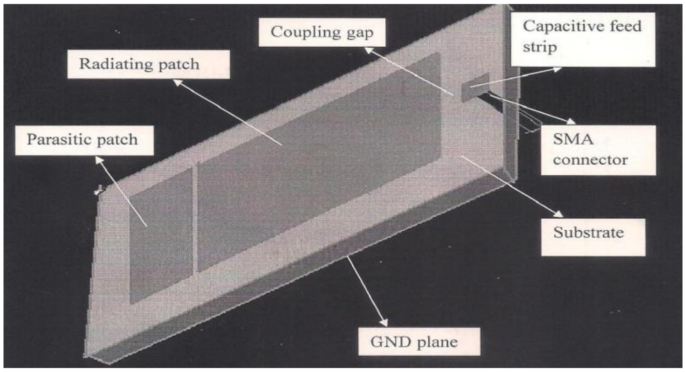

Figure 2: 3D-Structural View of the Antenna Configuration.

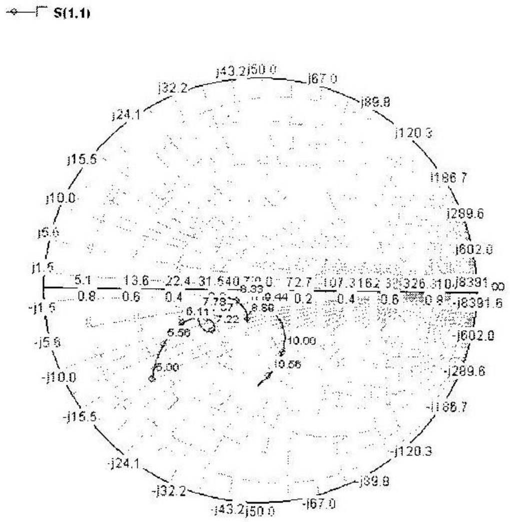

Figure 3: Smith Chart Showing Matching Of Input Impedance.

C. *Antenna dimensions*

The geometry of the microstrip antenna with a capacitive feed and a parasitic patch shown in fig. 1 is having parameters as:

1. Length of radiator patch=15.4mm
2. Width of radiator patch=16.4mm
3. Relative Dielectric constant of substrate=4.36
4. Thickness of substrate=1.57mm
5. Width of feed strip (t) =1.6mm
6. Distance between capacitive feed strip and radiating patch (d) =0.8mm
7. Length of feed strip (s) =2.8mm
8. Length of parasitic patch=4.5mm
9. Distance between parasitic patch and radiating patch=0.5mm

III. RESULTS

A. *Return Loss*

Return loss is a measure of impedance bandwidth for which the antenna is sufficiently matched to its input transmission line such that 10% or less of the incident signal is lost due to reflections. Impedance bandwidth measurements include the characterization of the Voltage Standing Wave Ratio (VSWR) and return loss throughout the band of interest. Return loss depends on the value of reflection coefficient (┌).Antenna return loss is calculated by the equations:

Return Loss= -10log|S11|^2 or 20 log (|┌|) ... (1)

Reflection coefficient (┌) = reflected wave/incident wave=Vo-/Vo+ … (2)

A good impedance match indicated by a return loss much less than -10dB. Fig.4 shows the experimental return loss obtained using IE3D. reflected multiple resonating frequencies at 6.8GHz ,8.45GHz and 9.45GHz and a overall bandwidth of nearly 5GHz ***(6.4GHz-10.4GHz)***, which is useful for UWB application. . Fig.5 shows the measured return loss, that was calculated using VNA (Vector Network analyzer).in this case a capacitive fed microstrip antenna along with the parasitic patch was implemented in hardware and was designed to use as transmitting antenna and was connected to port 1 of the VNA. For the stated antenna configuration the measured return loss indicated a bandwidth of more than 4GHz.

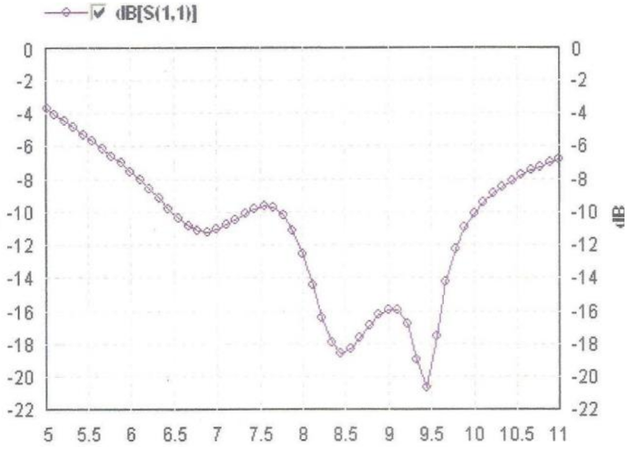

Figure 4: S11 Indicates bandwidth (6GHz-10.7GHz) at 10dB return loss using IE3D software.

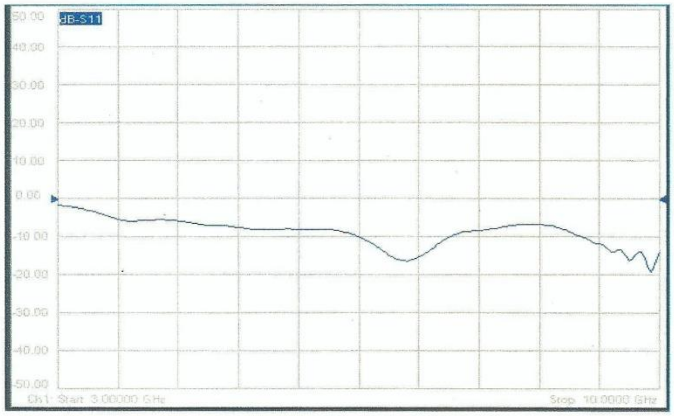

Figure 5: Measured bandwidth using VNA shows more than 4GHz at 10dB return loss.

Fig.6 shows the amount of agreement between the simulated and measured results of return loss.

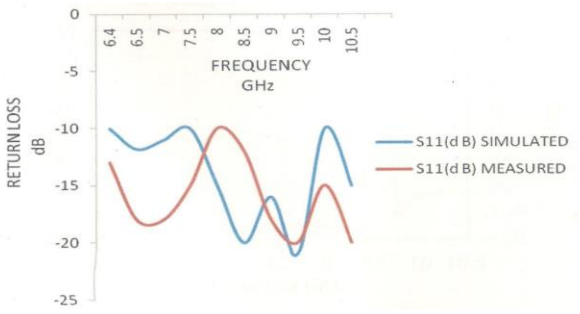

Figure 6: Simulated and measured return loss (S11) in dB versus Frequency in GHz

B. VSWR

VSWR is another parameter used for characterizing impedance matching for a given antenna configuration. Generally the desired value of VSWR to indicate a good impedance match between the feed and the driven patch is 2.0 or less. VSWR is measured as the ratio of amplitude of max. standing wave to min. standing wave and is given by the equation:

$$VSWR= V_{max} / V_{min}=(1+(|\Gamma|))/(1-(|\Gamma|)) \qquad \ldots(2)$$

From the VSWR performance antenna operating bandwidth extends from 6.4GHz to 10.4GHz within 2:1 range as seen from fig.7.

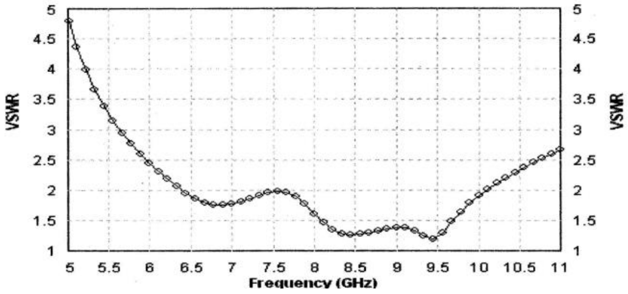

Figure 7: Frequency versus Voltage Standing Wave Ratio.

C. Gain

The gain of the stated antenna was experimentally obtained using IE3D shown in fig.8, and was also measured using VNA shown in fig.9. When there is a requirement for a highly directive antenna, like in case of UWB application, then gain gives a measure of the quality of the antenna. In this parameter's measurement, two identical stated antennas were designed in hardware .One of the antenna supposed to behave as transmitting antenna was connected to port1 of the VNA. Another antenna that is supposed to behave as receiving antenna was connected to port 2 of VNA. The distance between the two antennas is maintained as 'r', which is the minimum distance to receive far field. The transmission coefficient (S_{21}) is to be measured. Therefore, the transmitted power (P_t) and the received power (Pr) can be related to the transmission coefficient (S_{21}) by the equation,

$$Pr/ P_t =| S_{21}|^2 \qquad \ldots (3)$$

Then by using Friis transmission formula, gain of the receiving antenna is given by,

$$Gr = (4\pi r/\lambda) \mid S_{21}| \qquad \ldots (4)$$

For the stated antenna design, author have maintained the separation distance between the two antennas, r =15cm for an operating frequency of 7.38 GHz. Thus, wavelength, λ = 4.06cm is calculated. The measured value of 20 log | S_{21}| = -25.5dB (from VNA at 3.9 GHz).On applying log on both sides of eq.(4),

$$10 \log Gr = 10 \log (4\pi r/\lambda) + 10 \log | S_{21}| \quad \ldots (5)$$

Putting all the values of r and λ,

$$10 \log Gr = -16.8(25/2) =4.38dB \qquad \ldots (6)$$

Maximum measured gain of receiving antenna obtained is 4.3dB.

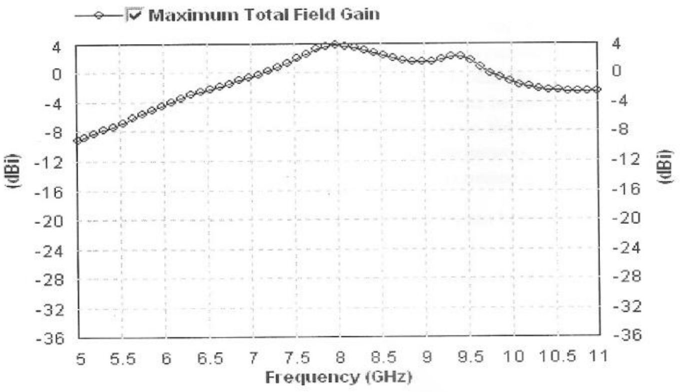

Figure 8: Simulated positive gain over the entire bandwidth.

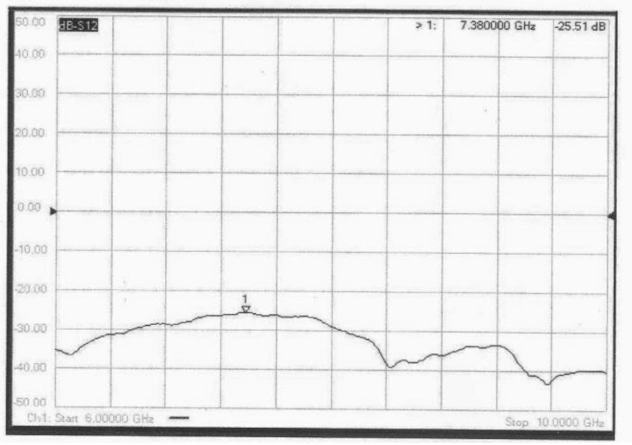

Figure 9: Measured transmission coefficient (S21) in dB.

D. *Radiation Pattern*

One of the most common descriptors of an antenna performance is its radiation pattern .It is a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. However from UWB communication point of view, antennas should be omnidirectional with a high directivity, such that majority of the radiated power is directed towards a specific known location. A two dimensional radiation pattern is plotted on a polar plot with varying φ between 0^0-90^0, for a fixed value of θ in azimuthal plane (E-plane).Fig.10 shows simulated circular polarization radiation pattern at two different resonating frequency , that is 8.44GHz and 9.44 GHz.

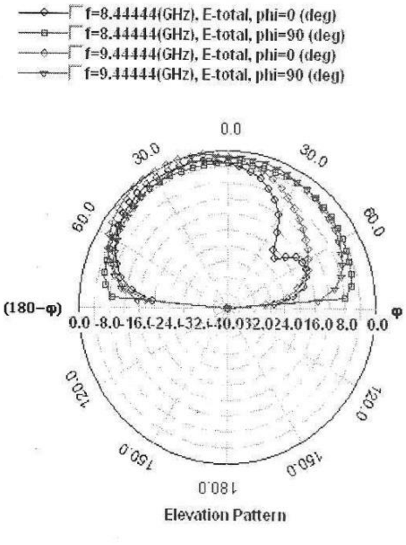

Figure 10: Simulated radiation pattern at two different resonating frequencies.

Fig.11 shows radiation pattern measured using microwave test bench. The radiation pattern although omnidirectional is slightly asymmetric due to capacitive loading.

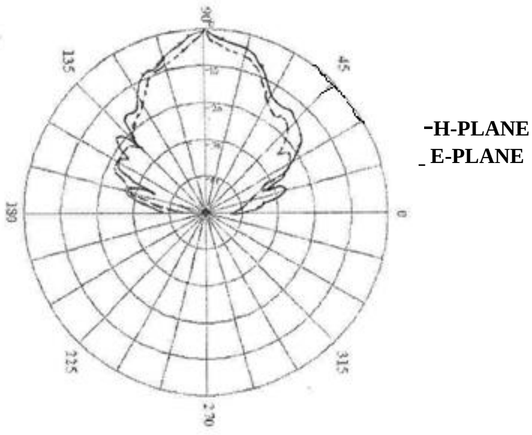

Figure 11: Measured Normalized Received Power Pattern at 9.0 GHz .

E. *Parametric study*

*Effect of change in distance between radiating patch and feed strip(d):*The distance ‘*d*’ has very small effect on the bandwidth,it does change the input impedance of the antenna.The resistive part decreases and reactive part(capacitive) increases with an increase in the distance ‘*d*’.If ‘*d*’ is kept in the range 1.0mm to 2.0mm, the antenna impedance exceeds VSWR=2 and the return loss characteristic curve splits into two separate bands.Fig.12 shows the effect od distance ‘*d*’ on the bandwidth of the stated antenna configuration.

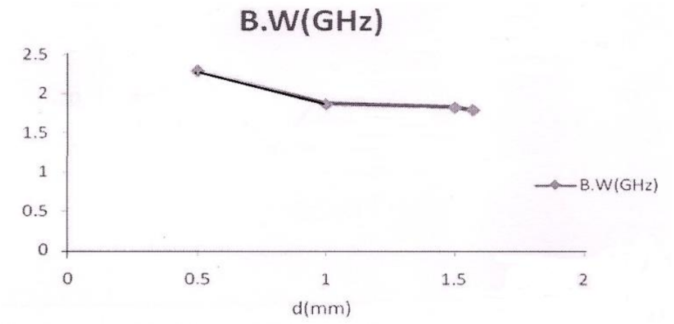

Figure 12: Distance versus Bandwidth

Fig.13 shows the hardware prototype of the stated antenna configuration.

Figure 13: Antenna Prototype

IV. CONCLUSION

The non-digital part of a UWB system makes its antenna design a particular challenging topic because there are more stringent requirements for a suitable WB antenna compared with a narrowband antenna. In this paper, a brief study of a compact microstrip UWB antenna with a parasitic patch fed using capacitive feed strip is presented. Several parameters were taken into account in analyzing strengths and weakness in potential antenna designs including impedance bandwidth, radiation pattern, and gain.

The results and discussions presented in this research should provide an intuitive perspective on fundamental requirements in design, testing and characterization of a UWB antenna.

In this paper, all the proposed antenna's measurements were carried out inside an anechoic chamber. However, in future UWB systems, antenna might be embedded inside a laptop or other devices. Thus, investigations on The devices effect on the antenna performances can be an objective of future work.

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