Accurate Determination of Antenna Impedance of Microstrip Line-Fed Patch Antennas

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Abstract:

Accurate determination of antenna impedance as we move from the edge of the patch antenna towards its center is an important issue to find the exact location of feed point where the antenna impedance is approximately 50Ω, which is usually the characteristic impedance of the microstrip feed lines. Few researchers have reported that microstrip-fed patch antennas follow the cosine fourth power variation whereas the coaxial probe fed patch antenna has cosine square variation. From our extensive simulation study we have observed that microstrip-fed patch antenna follows cosine fourth power variation for a feed location near the edges of the patch antenna and as the feed location move towards the center of the patch antenna it follows the cosine square variation and this changes occurs approximately between (L/5-L/4) distance from the edges towards the center which depends on the inset width.

Key Words: Antenna Impedance, Microstrip Line feed, Microstrip Patch Antenna

I INTRODUCTION:

The microstrip antenna concept dates back to about 26 years to work by Deschamps in U.S.A and Gutton and Baissinot in France. Shortly thereafter, Lewin investigated radiation from stripline discontinuities. Additional studies were undertaken in the late 1960's by Kaloi, who studied basic rectangular and square patch antenna configurations. However, other than the original Deschamps report, work was not reported in literature until the early 1970's when a conducting strip radiator separated from a ground plane by a dielectric substrate was described by Byron. This half wavelength wide and several-wavelength long strip radiator was fed by coaxial connections at periodic intervals along both radiating edges, and was used as an array for Project Camel. After that, a microstrip element was patented by Munson and data on basic rectangular and circular microstrip patches were published by Howell. Weinschel developed several microstrip geometries for use with cylindrical S-band arrays on rockets. Sanford showed that the microstrip element could be used in conformal array designs for L-band communication from a KC-135 aircraft to the ATS-6 satellite. Additional work on basic microstrip patch elements was reported in 1975 by Garvin, Howell, Weinschel, Janes and Wilson. The early work by Munson on the development of microstrip antennas for use as low-profile flush-mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems, and thereby gave birth to a new antenna industry. Mathematical modeling of the basic microstrip radiator was initially carried out by the application of transmission line analogies to simple rectangular patches fed at the center of a radiating wall [1]. A detailed background literature on the evolution of microstrip antenna technology is discussed by Carver [2].

Microstrip antennas have several advantages over conventional microwave antennas and they suffer from some limitations. The need to reduce these limitations has fuelled research into microstrip antennas over the past twenty years. Microstrip antennas find application in various fields because of their advantages like small size, low weight. It potential application includes mobile communications, telemetry especially in environments where good mechanical stability is needed example on missiles and rockets. One of the areas where microstrip antennas are being actively employed today is the wireless local area networks. We begin with discussing the advantages and limitations of microstrip antennas.

Microstrip antennas have many advantages over conventional microwave antennas. Some of the principal advantages of microstrip antennas over conventional microwave antennas are

- Light weight, low volume, and thin profile configurations
- Low fabrication cost; readily amenable to mass production
- Linear and circular polarization are possible with simple feed
- Dual frequency and dual polarization antennas can be easily made
- Can be easily integrated into microwave integrated circuits
- Feed lines and matching networks can be fabricated simultaneously with the antenna structure

However microstrip antennas do however suffer from serious limitations as compared to conventional microwave antennas

- Narrow bandwidth and associated tolerance problems
- Lower gain
- Most microstrip antennas radiate into half space
- Polarization purity is hard to achieve
- Lower power handling capacity
- Excitation of surface waves

Microstrip antennas fabricated on a substrate with high dielectric constant are preferred for easy integration with MMIC RF front-end circuitry. However use of high dielectric constant substrate leads to poor efficiency and narrow bandwidth. Various methods are used to increase the bandwidth of the microstrip antenna. These can be grossly categorized as

- Impedance matching
- Use of multiple resonance
- Reducing the quality factor of the antenna

II. ANTENNA IMPEDANCE

The accurate determination of antenna impedance is important because of the fact that most microwave sources and lines are manufactured with 50Ω characteristic impedance. No matter what the antenna impedance is we have to properly match it to a 50Ω source line or impedance. Matching techniques exist like the use of quarter wave transformer. This technique uses matching at a single frequency. There is a separate class of techniques called broadband matching which tries to match the transmission line over a broad frequency range. Use of triangular taper line and the binomial transformer are two popular methods. We will not go into the impedance matching techniques, as it is another area of research [3]. Instead we will try to locate the position of the feed point to the patch antenna where the impedance is 50Ω. Various feeding methods for microstrip antennas like microstrip line feed, aperture coupled feed [4], and coaxial feed capacitive feeding is available in literature. In this paper, we will concentrate on the microstrip line-fed patch antennas in order to maintain planarity of the antenna structure. Patch antenna design using microstrip line feed shows variation of input impedance depending on the position of the feed. Conventional design formula predicts a cosine square variation in the antenna input impedance depending on the position of the feed [5].

$$Z_{in} = Z_A \cos^2\left(\frac{\pi y_0}{L}\right)$$

where, Z_A is the input impedance of the antenna. Here the length of the inset is y_0, the width of the inset is s, W is the width and L is the length of the rectangular patch antenna.

III. RESULTS AND DISCUSSION

It has been reported in [6] that in case of coaxial probe fed patch antenna the antenna impedance shows the cosine square variation with feed position, but in case of microstrip line fed rectangular patch antenna the variation in input impedance is steeper and it follows the cosine fourth power variation. In their design the width of the microstrip line was b=0.38 cm giving a 50 ohm impedance for 2.3 GHz. The substrate used had a relative permittivity of 2.4 and thickness of 0.127 cm. The width of the inset chosen by them was 0.38 cm, which is same as the width of the microstrip feed line. No explanation has been provided as to why 0.38 cm was chosen as the inset width although it is possible to fabricate inset with width far less than 0.38 cm.

We have ourselves tried to venture into finding the approximate formula for variation of patch antenna input impedance. For this we have also varied the inset length and tried to capture the antenna impedance variation for three different inset widths of 0.2 mm, 0.4 mm and 0.6mm. We have designed a rectangular microstrip antenna with resonance frequency of 10 GHz on FR4 epoxy substrate, which has a relative permittivity of 4.4, and thickness was taken as 1.6 mm. As observed by Basiloi et al the change in input impedance with feed position has a characteristic feature when microstrip line feed is used. The patch antenna impedance decreases as the feed location approaches the center. But unlike their results we saw that only when the feed line is near the edge of the patch i.e. the inset width is less, the behavior is more close to the cosine fourth power variation. But as we move towards the center of the patch antenna cosine square formula is a better approximation of the antenna impedance. This change in cosine fourth power variation of antenna impedance to cosine square variation occurs when the feed location is in between L/5-L/4 approximately depending on the inset width. For wider inset it is approximately L/5 and for smaller inset width it is approximately L/4 as illustrated in Figure 1.

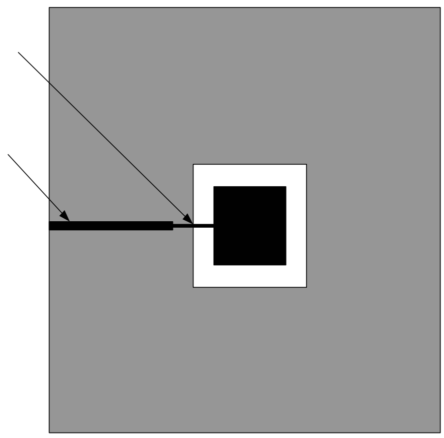

Fig. 1(a)

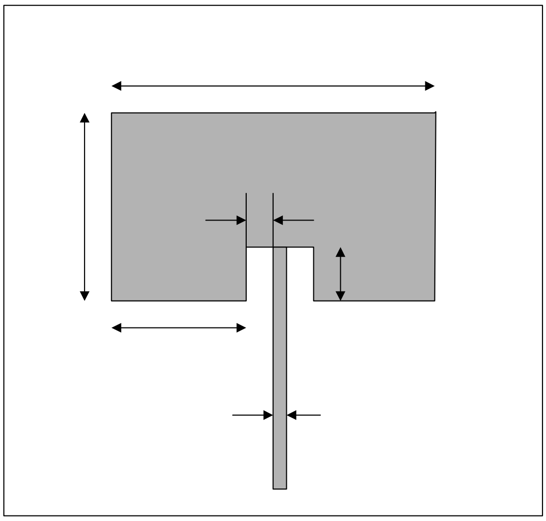

Fig.1(b)

Figure 1. (a) Rectangular patch antenna with quarter-wave microstrip line feed (b) Rectangular patch antenna with microstrip line feed showing the inset dimensions.

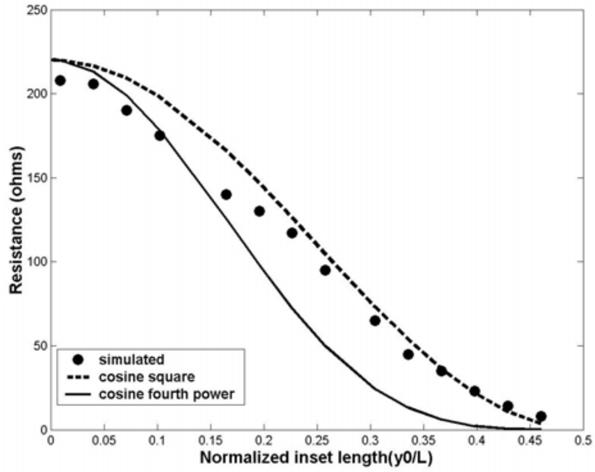

Fig. 2 (c)

Figure 2. Antenna resistance versus normalized inset length for different inset width values a) inset width 0.2 mm b) inset width 0.4 mm c) inset width 0.6 mm

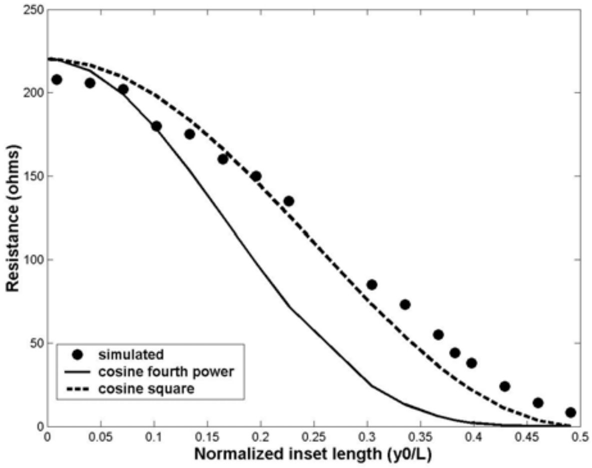

Fig. 2 (a)

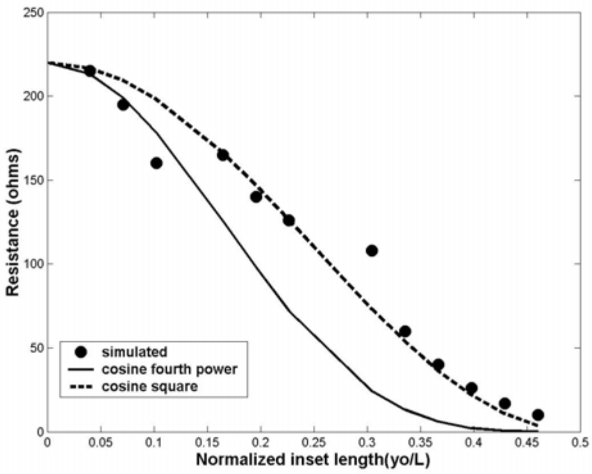

Fig. 2 (b)

CONCLUSION

Thus from our simulations we have concluded that the cosine fourth power variation of patch antenna holds in cases near the edges and cosine square law towards the center of patch antenna fed with microstrip line. Thus Basilio et al's work should not be treated as a general approximation for all microstrip line fed rectangular patch antennas. Our design differs from their design in three ways: firstly the dielectric material used has a relative permittivity of 4.4 and thickness of 1.6 mm, secondly the resonant frequency of the antenna is 10 GHz, and thirdly the inset width is different. Both substrate height and the inset width can influence the patch antenna impedance. In future we will verify this variation of microstrip-line fed patch antenna impedance for other substrate materials and for patch antenna operating in other frequency ranges.

ACKNOWLEDGMENT

Authors are grateful to staffs at the Systems Simulation Laboratory, IIT-Guwahati for their time and help in carrying out these simulation works.

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