Design of Dual Polarized Basestation Antenna for CELL Band Application using Parasitic Conductor

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ABSTRACT

In this paper, a design of CELL band dual polarized base station antenna having air dielectric substrates has been proposed. The study of dual polarized base station antenna and their radiation properties including return loss, isolation, beam width, directivity, and radiation patterns for a single element are discussed. The antenna has a relative bandwidth of 31.7% (VSWR<1.4) with return loss of -16.5 dB at both ports. The port decoupling is better than -20 dB in the entire frequency band. The broad bandwidth is achieved by optimization of the feeding network which is implemented as an aperture coupled Microstrip feed and achieves a gain of average 7dB.

Keywords

Aperture coupling, basestation antenna, dual polarization, , widebandwidth.

1. INTRODUCTION

Modern trends in wireless communications impose the need for design and development of efficient antenna elements used in products that will eventually operate in contemporary multi-service urban environments in which several different networks co-exist and interoperate. These antennas are necessary to operate in a wideband mode covering several different services. Base station antenna consists of an array of radiating elements, power divider and a phase shifter. Radiating element radiates and receives the signal. Power divider divides the power to each radiating elements. Phase shifter is used to tilt the beam in required direction.

Microstrip patch antennas have been one of the most popular types in the past decades, mainly due to their very low profile, low cost of fabrication, easy incorporation into planar arrays, light weight and compatibility with microwave integrated circuit technologies. These advantages in most cases were found to outweigh the main electrical disadvantages inherent to this type of radiator, such as narrow bandwidth, spurious feed radiation, poor polarization purity and limited power handling capabilities comparable with dipole [1] – [3]. And then the design of a dual-polarization stacked patch antenna to be used in GSM-UMTS (1700-2170 MHz) base station arrays is presented [2]. In this method, 24% bandwidth for isolation values of -36 dB at -24dB return loss but it is not advisable to design arrays for base station antennas because number of layers is more. The use of more layers increases the complexity and high cost.

Another problem is passive inter modulation (PIM) which is unwanted signal otherwise signals generated by the non-linear mixing of 2 or more frequencies in a passive device such as connector and cable. In Active device filtering, we can reduce the PIM but Passive device transmission line that causes PIM cannot be filtered. The only way to reduce PIM in the transmission path is to design low PIM device [5].

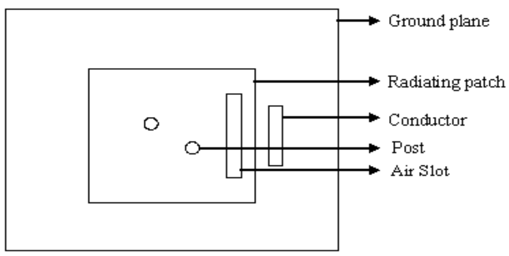
Several different techniques have been proposed in literature, concerning the enhancement of impedance bandwidth in Microstrip antennas, mostly by increasing the substrate thickness also substrate dielectric constant. This could cause extensive losses. In practical base station antenna design, we must reduce antenna to ground height, the substrate dielectric constant and thickness, and also we must reduce the use of number of fasteners.

In this paper, we present a new design for CELL band dual polarized base station antenna having air dielectric substrates. The study of dual polarized base station antenna and their radiation properties including return loss, isolation, beam width, directivity, and radiation patterns for a single element are discussed.

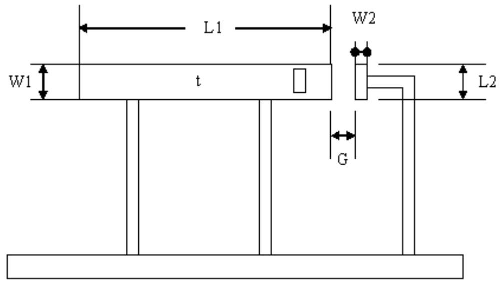
2. ANTENNA DESIGN

2.1 Microstrip Square Patch Antenna

Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in figure 1. The patch is generally made of conducting material such as Brass and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Length (L) of the patch is usually $0.3333\ \lambda_0 \leq L \leq 0.5\lambda_0$, where λ_0 is the free-space wavelength. The patch is selected to be very thin such that, $t << \lambda_0$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda_0 \leq h \leq 0.5\ \lambda_0$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$. In our case $\varepsilon_r = 1$ (air dielectric).



(a)



(b)

Fig.1 : Microstrip patch antenna
(a) Top view (b) Side view

TABLE I. DESIGN SPECIFICATION

Parameters	Description
L1 = 123 mm	Overall patch length
W1 = 123 mm	Patch width
L2 = 6 mm	Overall conductor length
W2 = 17 mm	Conductor width
t = 2 mm	Thickness of the patch and conductor
SL = 65 mm	Slot length
SW = 5 mm	Slot width
G = 1 mm	Coupling gap between the patch and conductor

To find wavelength, λ

$$\lambda = \frac{c}{f\sqrt{\varepsilon_r}} \qquad (1)$$

Where,

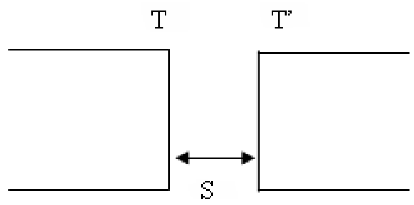
C = light velocity, 3×10^8 m/s
λ = Wave length
f = Frequency in MHz
ε_r = Relative permittivity

To find Length L,

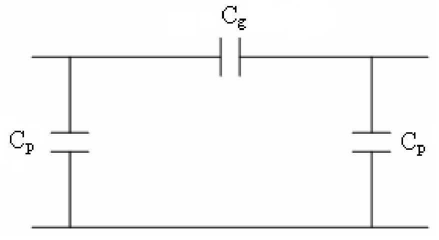
$$L1 = W1 = \frac{\lambda}{2} = \frac{361}{2} = 180.5mm \qquad (2)$$

To find Ground width,

$$d = \sqrt{180.5^2 + 180.5^2} = 256mm \qquad (3)$$



(a)



(b)

Fig.2 : Microstrip discontinuities
(a) Dicontinuity (b) Equivalent circuit

To find Capacitance C,

$$C = \varepsilon_o \varepsilon_r \frac{A}{d} \qquad (4)$$

Where,

C = Capacitance of the parallel plate
ε_o = Air dielectric constant, 8.854×10^{-12}
ε_r = Relative permittivity
A = Area
d = Distance in m^2

Let as assume,

S = G=4 m.m

W2 = 6 m.m

L2 = 17 m.m

h = 70 m.m

we know that,

$$\frac{S}{W} = \frac{4}{6} = 0.7 \le 1 \text{ for } 0.3 \le 0.7 \le 1 \qquad (5)$$

$$\frac{W}{h} = \frac{6}{70} = 0.086 \qquad (6)$$

$$m_e = \frac{1.565}{\left(W/h\right)^{0.16}} - 1 = \frac{1.565}{0.086^{0.16}} - 1 = 1.3174 \qquad (7)$$

$$K_e = 1.97 - \frac{0.03}{W/h} = 1.97 - \frac{0.03}{0.086} = 1.6212 \qquad (8)$$

$$\frac{C_o}{W} = 12\left(\frac{\varepsilon_r}{9.6}\right)^{0.9}\left(\frac{S}{W}\right)^{m_e} \exp\left(K_e\right) = 29.8276$$

(9)

$$C_p = 0.5C_e \tag{10}$$

$$C_p = \varepsilon_o \varepsilon_r \frac{W}{h} = 0.7614PF \tag{11}$$

$$C_e = \frac{C_p}{0.5} = \frac{0.7614}{0.5} = 1.5228PF \tag{12}$$

$$C_g = 0.5C_0 - 0.25C_e = 1.5228PF \tag{13}$$

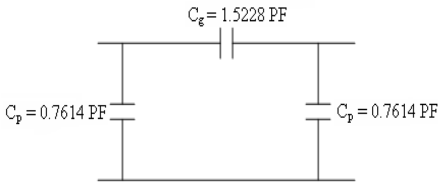


Fig.3: Equivalent circuit of discontinuities

2.2 Aperture coupled microstrip feed

For maximum coupling, the patch should be placed nearest to the gap. Moving the patch relative to the slot in the H-plane direction has little effect, while moving the patch relative to the slot in the E-plane direction will decrease the coupling level. Base station antennas mainly operate in a linearly polarized mode. The propagation efficiency is more favorable to the vertical polarization than horizontal system.

Dual polarized antenna which is capable of simultaneously radiating electromagnetic waves in polarized direction of -45^o and +45^o for the required electromagnetic wave coverage.

3. Simulation and results

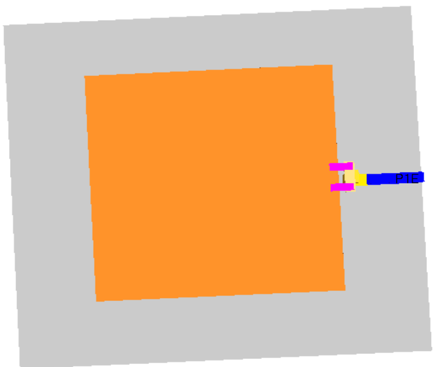


Fig.4: Single element patch antenna

Figure 4 shows the layout of the single polarized patch antenna and relation between the return loss and its frequency in MHz range is shown in figure 5. Return loss of -15dB is obtained from 700-960 MHz of overall bands.

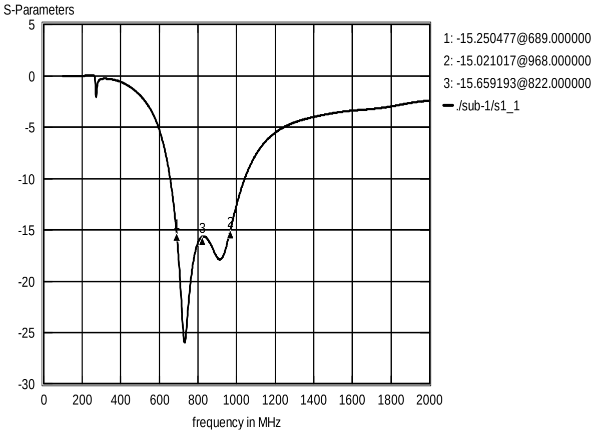


Fig.5 : S-parameter for single element

The impedance matching is plotted in figure 6. Maximum impedance matching of 50 ohms over the frequency band was achieved in this structure. This figure shows single polarization based impedance matching circuit. Gain over the frequency is plotted in figure 7 and above 5dB gain was achieved over all bands.

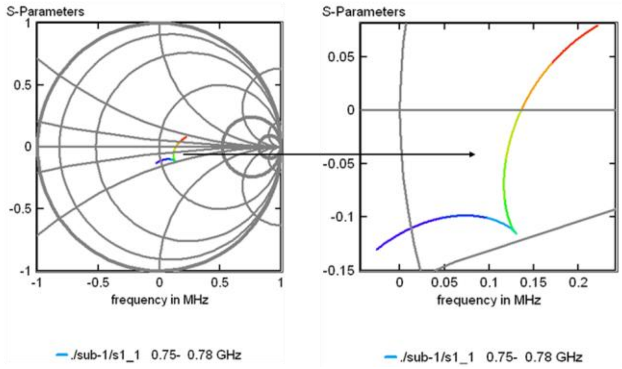


Fig.6: Impedance matching for single element

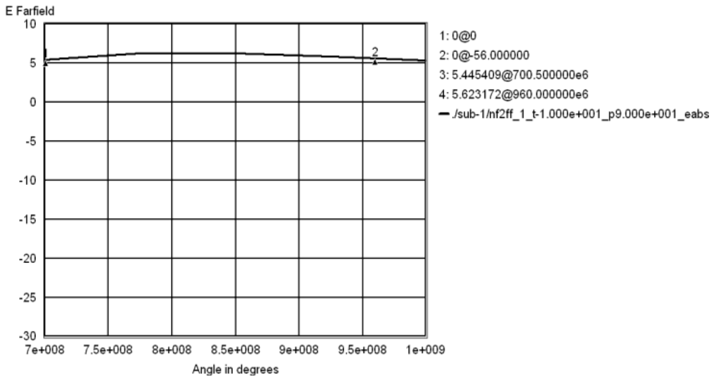


Fig.7: Gain of single element

The layout of the single element dual polarized structure is plotted in figure 8. The simulated return loss is plotted in figure 9 and its return loss, isolation in table 2. More return loss and isolation in cut off frequency of 850 MHz In particular frequency more isolation of above -20 dB between port 1 and 2 was achieved.

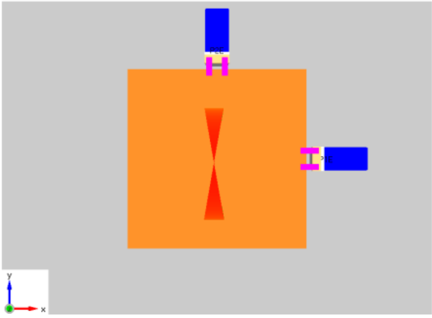


Fig.8: Single element X-pole patch antenna

TABLE II. SIMULATED S-PARAMETERS

Frequency (MHz)	S11 in dB	S21 in dB
708	-15.1	-16.2
848	-15.11	-22.3
928	-15.25	-15.6

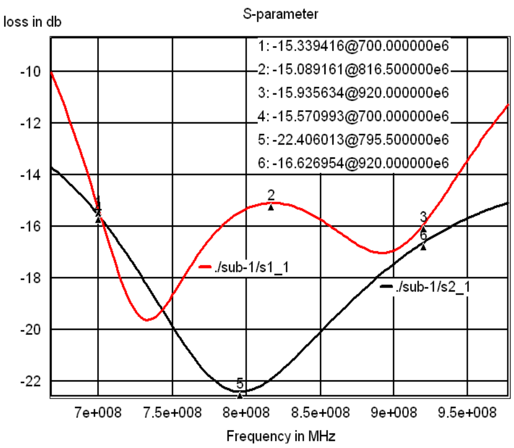


Fig.9: S-parameter for single element X-pole

The impedance matching is plotted in figure 10. In this structure we have achieved a maximum impedance matching over the frequency band of 50 ohms. Radiation pattern for H-field in figure 12 which is the angle between the half power points of the main lobe(H-field), when reference to the peak effective radiated power of the main lobe(E-field). In this design achieved 7 dB of peak effective radiated power in E-field direction and 98 degree of beam width was achieved in H-field direction.

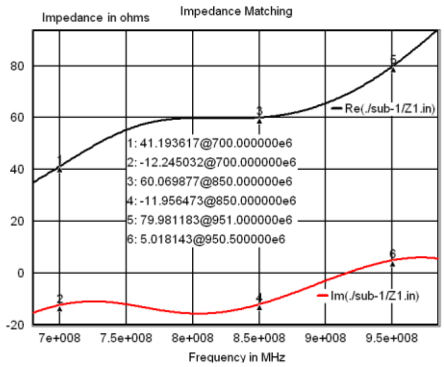


Fig.10: Impedance matching for single element X-pole

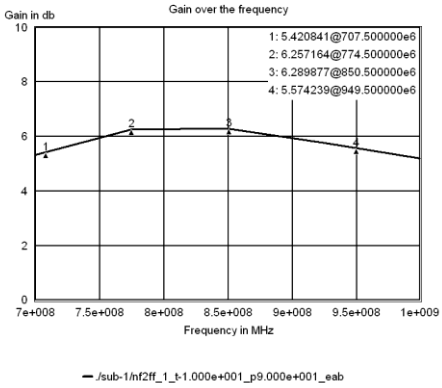


Fig.11: Gain of single element X-pole

Gain over the frequency is plotted in figure 11 and its simulated result in table III. In this paper ±1 dB deviation gain was achieved and maximum gain is 7 dB at 850 MHz for single element.

Table III. Simulated Antenna Gain

Frequency (MHz)	Antenna Gain (dB)
708	6.3
848	7.1
928	6.2

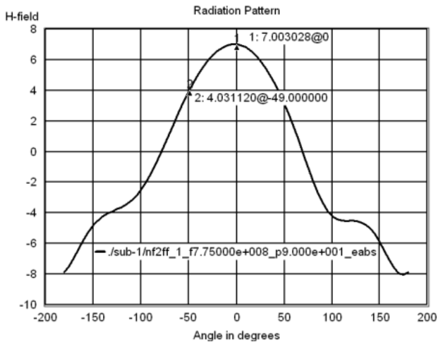


Fig.12: Radiation pattern of single element X-pol

4. CONCLUSION

A wideband dual polarized patch antenna has been presented in this paper, with air dielectric substrate. A good agreement has been proved between simulated results, in terms VSWR. With the proposed design process, the achieved bandwidth of the prototype antenna was measured at 31.7%, operating continuously over the frequency range between 700 to 960 MHz, for an acceptable VSWR less than 1.4:1. Enhanced bandwidth is achieved through optimum coupling gap with aperture feeding method, thus providing greater bandwidth while maintaining structural simplicity over previously proposed designs. The requirements of low PIM, reduced number of fasteners, and good isolation are met by its low-profile and ease in assembling.

In future, a design a wide bandwidth dual polarized antenna with reduce antenna height of quarter wave length can be done to achieve wider beam width, and to reduce the overlapping area of unwanted area in cell sectorization through back lobe and side lobe suppression.

5. ACKNOWLEDGMENT

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6. REFERENCES

[1] K. R. Carver, J.W. Mink, "microstrip antenna technology", IEEE Trans Antennas Propagat, Vol. AP-29, No. 1, (1981), 2-24.

[2] David Weinstein, "Passive inter modulation distortion in connectors, cable and cable assemblies", Amphenol corporation communication and network products Danbury.

[3] D.M. Pozar, "Microstrip antennas", Proceedings of the IEEE, Vol. 80, No. 1, (1992), 79-91.

[4] Microstrip antenna design handbook – Ramesh Garg, Prakash Bharatia, Inder Bahl, Apisak Ittipiboon.

[5] David M. Pozar, "A Review of Aperture Coupled Microstrip Antennas: History, Operation, Development, and Applications", May 1996.

[6] Targonski, S.D.R.B. waterhouse, and D.M.Pozar, "Design of wideband Aperture stacked patch microstrip antenna", IEEE Trans on antennas and propagation.

[7] C.A. Balanis, Antenna theory, john wily & sons inc., (1997).

[8] Beatriz Aja, Eduardo Artal, M. Luisa de la Fuente, Juan P. Pascual, "Effective Bandwidth Improvement Technique Based On Mismatch Analysis", IEEE Trans on antennas and propagation

[9] E.C. Jordan, G.A. Deschamps, J.D. Dyson and P.E. Mayes, "Developments in broad band antennas, IEEE spectrum pages 58-71 April 1964.

[10] Shigeru Egashira and Eisuke Nishiyama, "Stacked Microstrip antenna with wide bandwidth and high gain", IEEE transactions on antennas and propagation, vol,44. No. 11, November 1996.

[11] Mariano Barba, "A High-Isolation, Wideband and Dual-Linear Polarization Patch Antenna", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 56, NO. 5, MAY 2008.

[12] E.F. Bolinder, "Geometrical Analysis of partially polarized electromagnetic waves", IEEE Trans.antennas propagation vol.AP-15,No.1,pp. 37-40 January 1967.

[13] E.H. Vanlil and A.R.Van de capelle, "Transmission line model for mutual coupling between microstrip antennas", IEEE Trans. Antennas propagation vol. AP-32,No.8,pp 816-821.Auguest 1984.

[14] D.H.Schaubert, D.M.Pozar, and A.Adrian, "Effect of microstrip antenna substrate thickness and permittivity: comparison of theories and experiment", IEEE Trans. Antennas propagation vol AP-37,No.6 pp 677-682, June 1989.