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A Broadband Vertical Polarized Antenna for Wireless Communications

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Abstract – **A folded metal dipole is of considerable interest as a broadband antenna element, and has good potential for use in low cost wireless base station antenna applications. In this paper, experimental and simulation results are presented which include a metal vertical polarized dipole alone and arranged in a staggered six element array. The results show that this dipole element and the six staggered dipole array have excellent gain performance and radiation pattern profile. The measured and simulated results for both the element and the array are in good agreement.**

1 INTRODUCTION

An ideal base station antenna for use in wireless communications would have broadband performance, small aperture, high gain, low side lobe levels, and the required appropriate beam width for cell sector design. In addition, power handling (500 Watts for Cellular band) must be adequate, intermodulation levels must be low, and assembly and manufacturing must be easy and geared for high volume. Increasingly, cost is a major factor, especially for applications in the emerging markets. In existing designs, the use of parabolic reflectors and aperture-coupled stacked patch elements, lead to good performance, but have had difficulty achieving required cost targets due to the use of extensive cabling and high cost printed circuit boards.

The proposed new folded metal dipole with broadside coupled paired stripline feed provides broadband performance of ~18% bandwidth (806 – 960 MHz for AMPS/CDMA/GSM). As it is composed of bent sheet metal, it provides the high power handling required, and provides for ease of assembly as needed for volume production. Figure 1 illustrates the single dipole. This dipole is fed from a broadside coupled paired stripline which also supports the dipole from the ground plane. The antenna element is composed of two conductors formed from a sheet of conductive material, in this case aluminum. One conductor is attached to ground with the dipole arm towards one side, while another conductor attaches to a microstrip input feed line spaced above the ground plane with the dipole arm towards the opposite side. The dipole radiator input has intrinsic impedance, and the impedance of the supporting broadside coupled paired stripline is adjusted by varying the width of the conductor sections and the gap. Therefore, the input impedance of the dipole is matched to the impedance of the microstrip by adjusting the impedance of the broadside coupled paired stripline. The two legs supporting the dipole form a balanced broadside coupled stripline transmission line. The transmission line is balanced, so it is unnecessary to provide a balun.

The structure described above and shown in Figure 1 provides a vertical dipole element with very wide impedance bandwidth. Figure 2 shows a prototype of the Figure 1 design including side reflectors on the ground plane. As will be shown, this prototype has Half Power Beam Width (HPBW) of 90° in the ground plate azimuth plane. Based on the single element prototype in Figure 2, a staggered six element array prototype was constructed as shown in Figure 3 was designed with a goal of achieving an azimuth plane 65° HPBW. Simulated and prototype measured results for both the single dipole and the staggered six dipole array antennas are presented below.

2 THEORY AND DESIGN

The single dipole element, as shown in Figure 1, consists of a dipole element supported by a Broadside Coupled Paired Stripline (BCPSL), and a one-stage quarter wavelength transformer in microstrip line. The BCPSL is balanced, and provides excitation to the dipole. Moreover, the bandwidth of the BCPSL is ultra wide. The length of the dipole is approximately a half wavelength (~170mm) at the center frequency of the 806 – 960 MHz band which is 883 MHz, and the height of the dipole above the ground plane is about a quarter wavelength (~85mm). This geometry will provide the optimal gain performance with the expected 90° HPBW in the azimuth plane and 65° HPBW in the elevation plane based on the expected reflector size.

The energy transfer between the BCPSL and the dipole was designed using the Method of Moments (MoM) software IE3D of Zeland^{TM} software Inc. The analysis results show the input impedance of the

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dipole at the bottom of the supporting BCPSL to be about 135 Ω. The impedance was transformed using one stage of quarter wavelength transformer is microstrip line providing an input impedance 50 Ω. Figure 4 shows simulated return loss results of the single dipole including the single stage quarter wavelength transformer. The radiation pattern of this design was predicted using the commercial software EZNEC. Both the model and simulation results for the single dipole design are shown in Figure 5 and Figure 6, respectively. The simulation results show the desired ~90° and ~65° HPBW in horizontal and vertical planes.

The feed network for the six staggered dipole array antenna was designed using IE3D, as shown in Figure 7. The feed network is parallel in-phase with a Dolph-Chebyshev amplitude power distribution taper providing -18 dB side lobe suppression. The s-parameter simulation results of the feed network from IE3D are shown in Figure 8. The radiation pattern of the array was predicted using EZNEC. Both model and simulation results are given in Figure 9 and Figure 10, respectively. The simulated results predict a directivity of about 15 dBi across the 806 – 960 MHz band.

3 EXPERIMENTAL RESULTS

In order to verify the simulation results, a single vertically polarized dipole was built and tested. Figure 11 and Figure 12 show the measured patterns in the azimuth and elevation planes; approximately 90° in azimuth and 65° in elevation plane. A six staggered element antenna array was fabricated and tested. The prototype is shown in Figure 3. Figure 13 and Figure 14 show the measured azimuth and elevation radiation patterns. Figure 15 provides the measured gain performance across the 806 – 960 MHz band. The measured patterns were taken in a 21 by 12 by 10.5 meter (L, W, H)) compact range having a 3 by 3 by 3 meter (L, W, H) quiet zone with attenuation of 50 dB.

4 CONCLUSION

A folded metal dipole with a reflector plate operating alone and a staggered six element array were presented. Prototypes for both antenna types were designed, built, and tested. Excellent impedance bandwidth was achieved. Good radiation patterns and gain for both the single dipole and array antenna were obtained. Both antennas radiate very efficiently across the 806 – 960 MHz band. The measurement results are in good agreement with the simulation results provided by IE3D and EZNEC. Both simulation and measurement indicate that simple low cost antennas for base station systems can be constructed using folded metal dipoles achieving both excellent performance and cost benefits.

Acknowledgments

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References

[1] R.C. Johnson, “Antenna Engineering Handbook”, Third Edition, 1993, chapter 4-4.

[2] B. C. Wadell, “Transmission Line Design Handbook”’ 1991, pp226.

[3] C. A. Balanis, “Antenna Theory”, Second Edition, 1996.

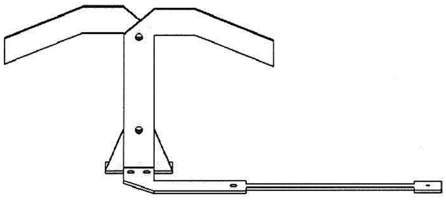


Figure 1: Single dipole fed by paired stripline

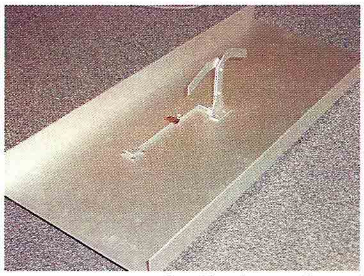


Figure 2: Prototype of a dipole on the reflector

Figure 3: Prototype of the 6 element array

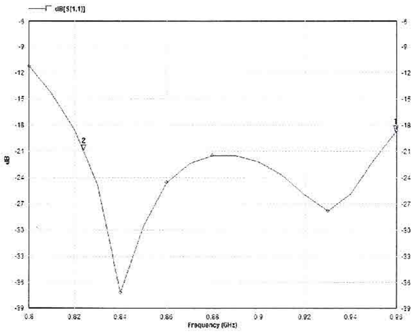


Figure 4: Simulation result on single dipole

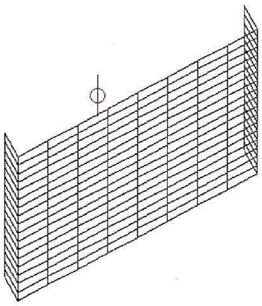


Figure 5: Single dipole model in EZNEC

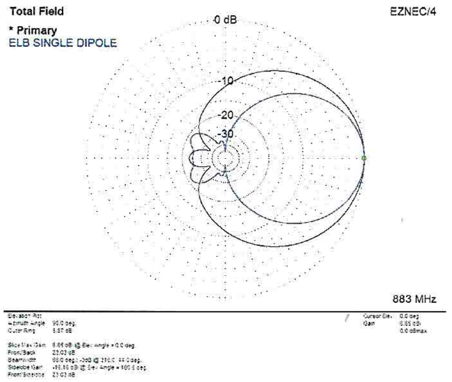


Figure 6: Predicted AZ and EL pattern of the dipole

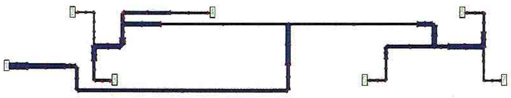


Figure 7: Feed network model in IE3D

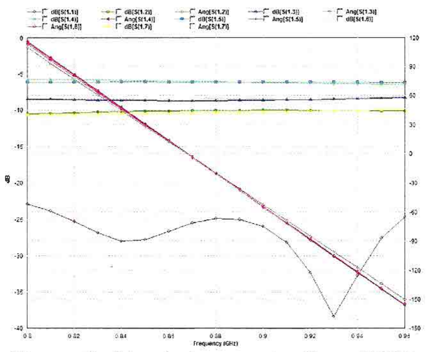


Figure 8: Simulation results from IE3D

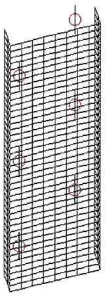


Figure 9: 6 staggered element model in EZNEC

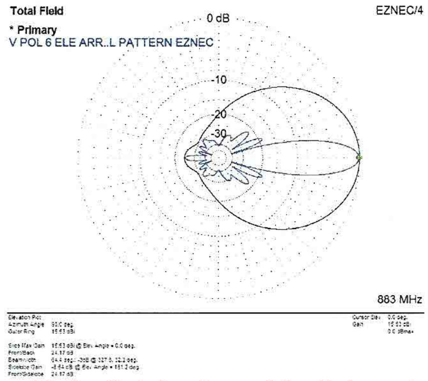
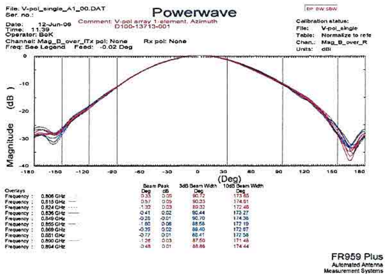


Figure 10: Predicted pattern of the 6 element array



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Chan.: Mag_B_over_R
Units: dBi

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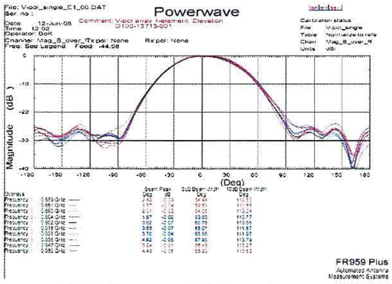
Frequency :	0.824 GHz	-1.32	0.03	89.32	172.46
Frequency :	0.836 GHz	-0.41	0.02	90.44	173.27
Frequency :	0.849 GHz	-0.20	-0.01	90.70	174.36
Frequency :	0.855 GHz	-1.60	0.06	88.58	172.19
Frequency :	0.869 GHz	-0.35	0.02	89.40	172.87
Frequency :	0.881 GHz	-0.77	0.01	88.41	172.58
Frequency :	0.890 GHz	-1.26	0.03	87.50	171.48
Frequency :	0.894 GHz	-0.48	0.01	88.86	174.44

Figure 11: Measured AZ pattern of dipole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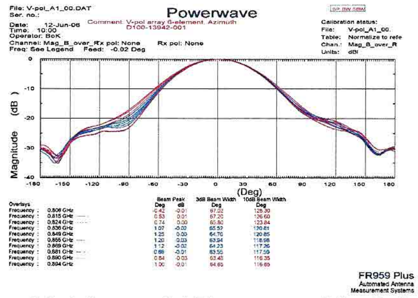
Chan: Mag_B_over_R
Units: dBi

Figure 12: Measured EL pattern of dipole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Freq: See Legend Feed: -0.02 Deg

Comment: V-pol array 6-element, Azimuth
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Calibration status:
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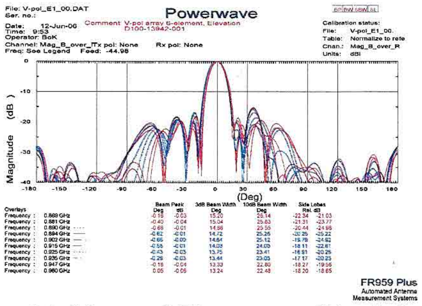
Table: Normalize to refe
Chan.: Mag_B_over_R
Units: dBi

Overlays		Beam Peak Deg	Beam Peak dB	3dB Beam Width Deg	10dB Beam Width Deg
Frequency :	0.806 GHz	-0.42	-0.01	67.02	125.30
Frequency :	0.815 GHz	0.53	0.01	67.20	126.60
Frequency :	0.824 GHz	0.74	0.00	65.80	123.84
Frequency :	0.836 GHz	1.07	-0.02	65.52	120.81
Frequency :	0.849 GHz	1.25	0.00	64.70	120.85
Frequency :	0.855 GHz	1.20	-0.03	63.94	118.98
Frequency :	0.869 GHz	1.12	-0.02	64.23	117.26
Frequency :	0.881 GHz	0.86	-0.01	63.55	117.59
Frequency :	0.890 GHz	0.84	-0.03	63.46	116.35
Frequency :	0.894 GHz	1.00	-0.01	64.65	116.65

Figure 13: Measured AZ patterns of the 6 element array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D100-13942-001

Calibration status:
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Table: Normalize to refe
Chan.: Mag_B_over_R
Units: dBi

Overlays		Beam Peak Deg	Beam Peak dB	3dB Beam Width Deg	10dB Beam Width Deg	Side Lobes Rel. dB	
Frequency :	0.869 GHz	-0.16	-0.03	15.20	26.14	-22.34	-21.03
Frequency :	0.881 GHz	-0.40	-0.04	15.04	25.83	-21.31	-23.77
Frequency :	0.890 GHz	-0.66	-0.01	14.86	25.55	-20.44	-24.98
Frequency :	0.894 GHz	-0.62	-0.01	14.72	25.26	-20.25	-25.22
Frequency :	0.902 GHz	-0.66	-0.00	14.64	25.12	-19.78	-24.92
Frequency :	0.915 GHz	-0.55	-0.01	14.05	24.03	-18.11	-22.61
Frequency :	0.925 GHz	-0.43	-0.03	13.75	23.41	-16.91	-20.26
Frequency :	0.935 GHz	-0.26	-0.03	13.44	23.03	-17.17	-20.23
Frequency :	0.947 GHz	-0.18	-0.04	13.33	22.80	-18.27	-19.56
Frequency :	0.960 GHz	0.05	-0.06	13.24	22.48	-18.20	-18.65

Figure 14: Measured EL patterns of the 6 element array

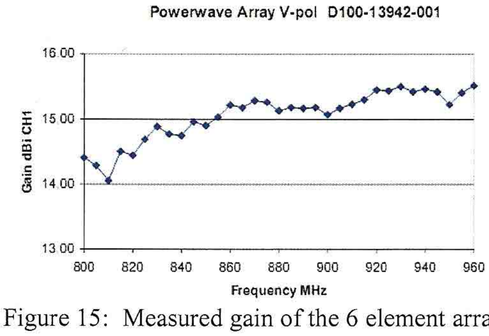

Figure 15: Measured gain of the 6 element array