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PERFORMANCE STUDY OF DIPOLE AND ITS VARIANTS IN BROADBAND SCENARIO

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Abstract—In this paper, the comparison of the performances of planar broadband dipole antenna, broadband folded dipole antenna and broadband bent dipole antenna in broadband scenario is presented. All the three antennas have been designed, developed and evaluated for their electrical characteristics, such as VSWR, radiation patterns and gain in the frequency range of 100–1000 MHz. Simulated and measured results are presented.

1. INTRODUCTION

The wire antennas such as dipole, monopole and their variants are narrow band antennas exhibiting 2% to 10% bandwidth depending upon the λ/D ratio [1]. The bandwidth of a dipole/monopole antenna can be increased if these antenna elements are designed with full electrical length ($\lambda/2$ for dipole and $\lambda/4$ for monopole) and lesser λ/D ratio [2]. In bent dipole, the effective length of the elements is increased by bending the antenna elements back toward the feed point. This increase in electrical length shifts the resonance frequency toward the lower frequency side and the antenna can be realized in lesser length [3]. This is required to accommodate a dipole antenna into available restricted space. Folded dipole naturally provides more bandwidth because its elements behave as short circuited stubs at lower frequencies and compensate the capacitive reactance of the antenna [4]. Among these three antenna configurations with similar dimensions the folded dipole provides maximum bandwidth of the order of 25–35%, if we require still more bandwidth then different impedance matching techniques are to be used [5]. In this approach, the frequency

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dependent antenna impedance is matched to $50\,\Omega$ source with the help of impedance matching network and a narrow band antenna can be transformed into broadband antenna. At higher frequencies (in GHz range) the dipole and its variants can be designed to work for broad bandwidth because at these frequencies the physical size of these antennas is lesser. The practical size of these antennas is less and hence they can be designed in fat form (less λ/D ratio) providing broad bandwidth with lesser form factors. For various applications, resonant/broadband/multiband dipole and its variants are designed and developed successfully [6–13]. In practical situation it is very difficult to maintain the λ/D ratio of similar order (less λ/D ratio, which is easily possible at higher frequencies) at lower frequencies. At lower frequencies the λ/D ratio is higher even for practical dimensions of the antennas and hence at these frequencies, wire/planar antennas are narrow band antennas. These antennas works fine in their limited band of frequencies. Comparatively, how these antennas will behave electrically if they are designed to operate in multi-octave frequency bandwidth? This investigation is carried out in this work. In this paper, the performance of matched broadband dipole, folded dipole and bent dipole antennas are investigated in the frequency band of 100–1000 MHz and the electrical performances are compared.

2. ANTENNA DESIGN AND REALIZATION

The size of printed antenna element is selected as $300\,\text{mm} \times 35\,\text{mm}$ (Length $\times$ Width) for all the three antenna configurations. Electrically, this length is $\lambda/2$ with λ/D ratio of 17.1 at 500 MHz. For folded dipole the spacing between two printed conductors is kept as 5 mm. The bent dipole model is derived from this model by providing an electrical discontinuity (gap) in the main element at the centre. All three antennas were simulated for their impedance and radiation characteristics using method of moment based EM simulation software FEKO$^{\text{TM}}$ suite 5.5 [14]. Simulation models of these three antenna configurations are shown in Figs. 1(a)–(c).

These antennas are realized in printed form on FR4 substrate. Dipole and folded dipole are printed on two separate substrates. The bent dipole is derived from folded dipole by cutting the folded dipole element at centre (opposite to feed point). A broadband impedance matching network and balun (not reported here) has been designed, developed and integrated at the antenna feed point. The same impedance matching network and balun are used with all three antenna configurations. The photograph of printed broadband dipole, folded dipole and bent dipole are shown in Figs. 2(a), 2(b), 2(c), respectively.

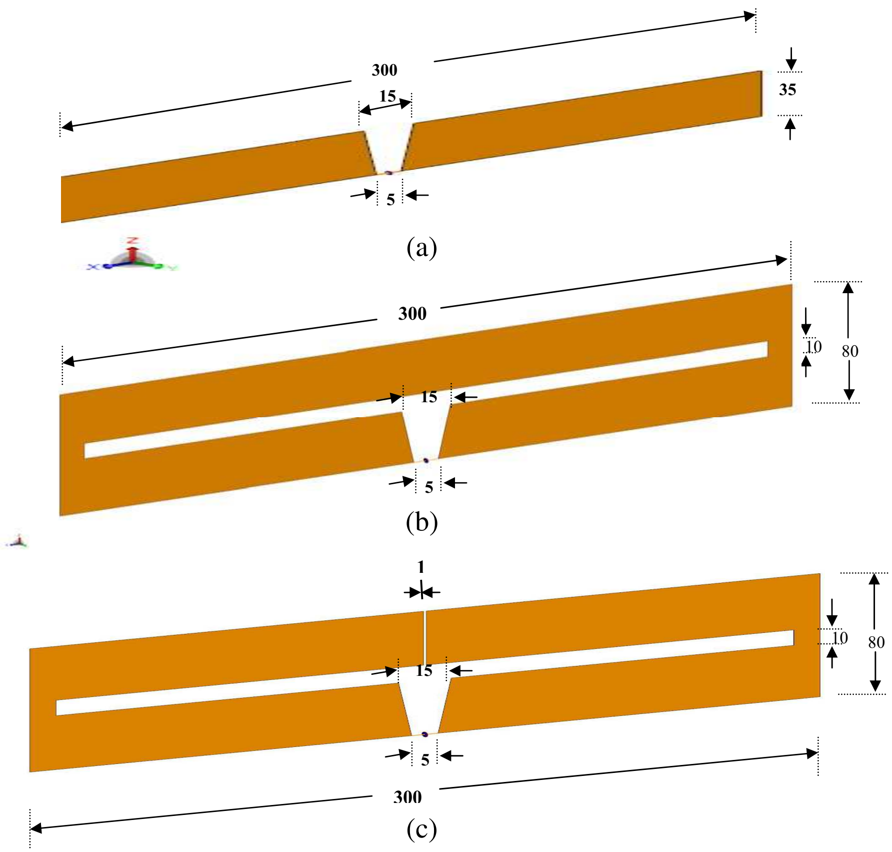


Figure 1. (a) Simulation model of dipole antenna. (b) Simulation model of folded dipole antenna. (c) Simulation model of bent dipole antenna.

3. SIMULATED AND EXPERIMENTAL RESULTS

Without impedance matching, simulated and measured results show the narrow band behavior of all three antenna configurations. Folded dipole shows comparatively more bandwidth as expected. These results without matching are not shown here. Broadband impedance matched antennas were evaluated for their impedance characteristics using vector network analyzer E5071C. Comparison of the measured VSWR plots is shown in Fig. 3.

The measured VSWR is $\leq 3.5 : 1$ over the band. Although VSWR profiles for three antennas are different due to their different impedance behavior over the band, it is observed that impedance bandwidth

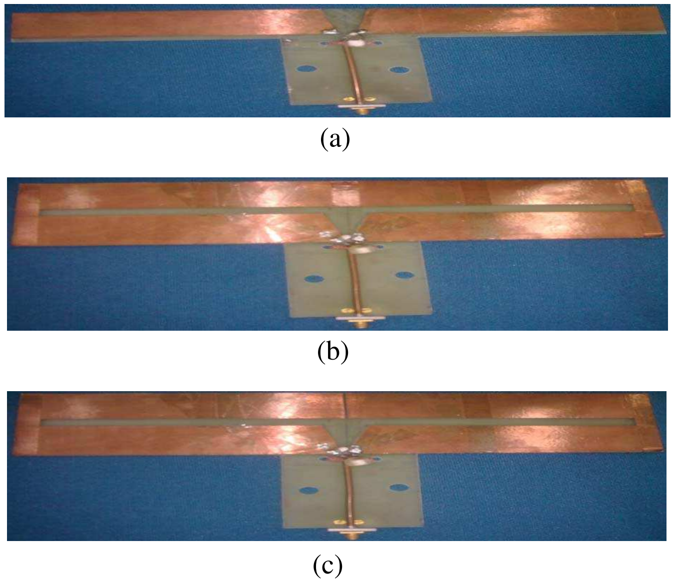


Figure 2. (a) Photograph of broadband dipole antenna. (b) Photograph of broadband folded dipole antenna. (c) Photograph of broadband bent dipole antenna.

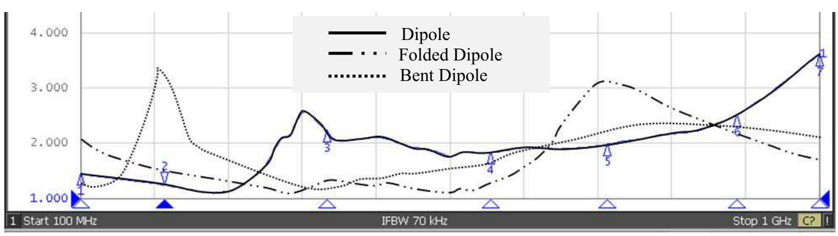
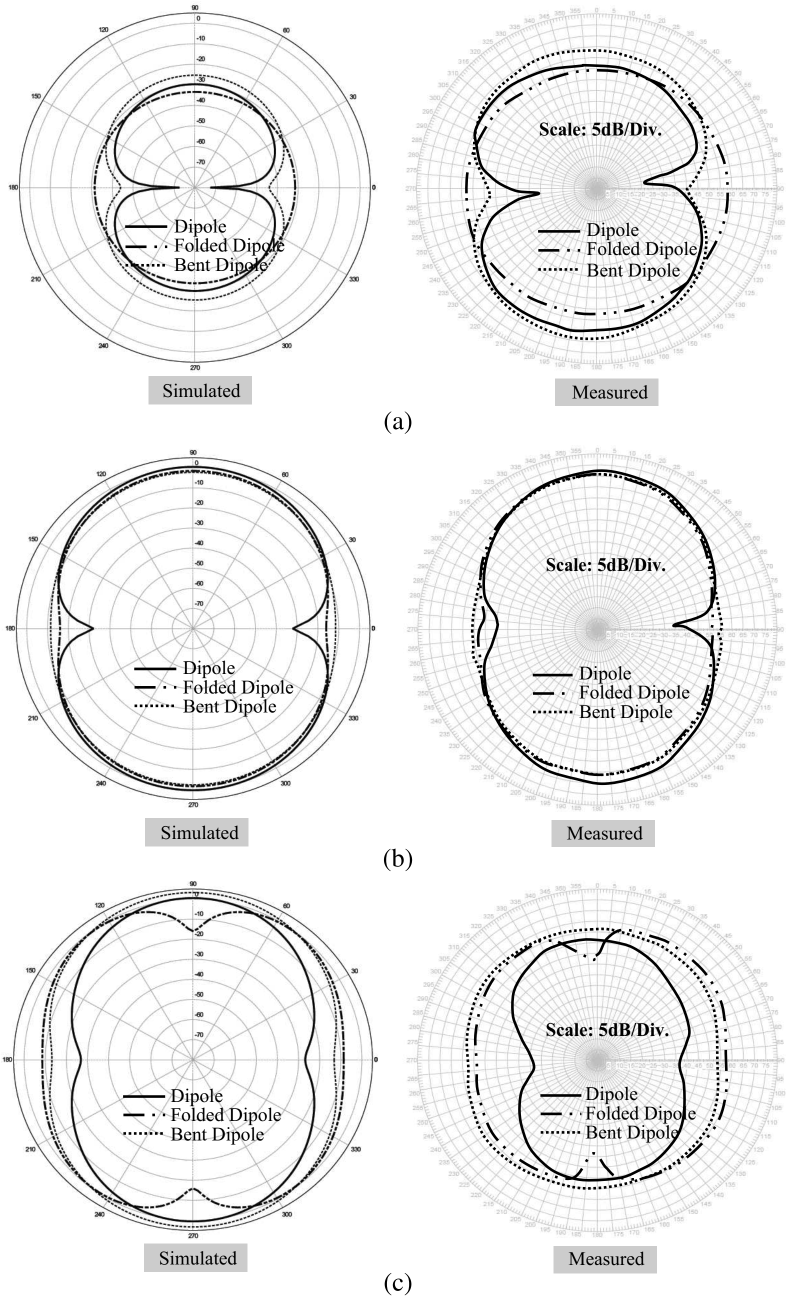


Figure 3. Comparison of measured VSWR plots of broadband dipole, folded dipole and bent dipole antennas.

is more or less same for all three antenna configurations with same impedance matching network.

The simulated and measured elevation and azimuth plane radiation patterns for these antennas are shown in Figs. 4(a)–(g) and Figs. 5(a)–(g), respectively. Simulated gain comparison of these three antenna configurations is shown in Fig. 6.

From simulated and measured radiation patterns and simulated gain, it is found that bent dipole provides better gain at lower


Dipole
Folded Dipole
Bent Dipole
Scale: 5dB/Div.
Dipole
Folded Dipole
Bent Dipole
Simulated
Measured
(a)
Dipole
Folded Dipole
Bent Dipole
Scale: 5dB/Div.
Dipole
Folded Dipole
Bent Dipole
Simulated
Measured
(b)
Dipole
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Dipole
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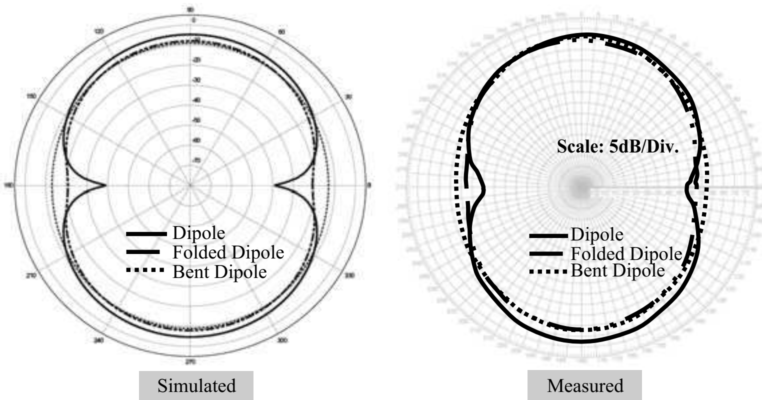
(c)


Dipole
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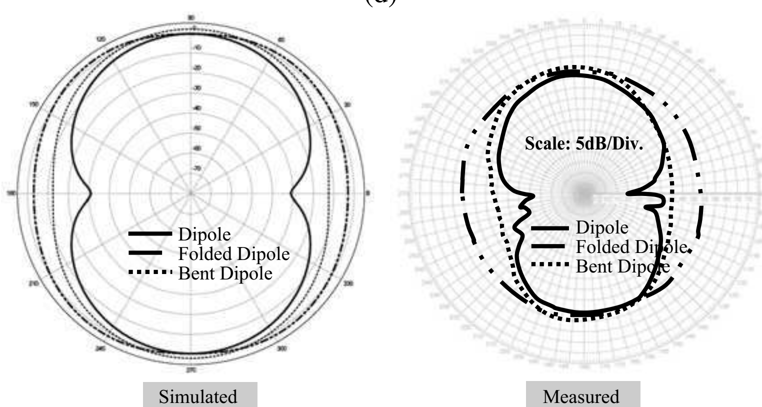
(d)


Dipole
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Dipole
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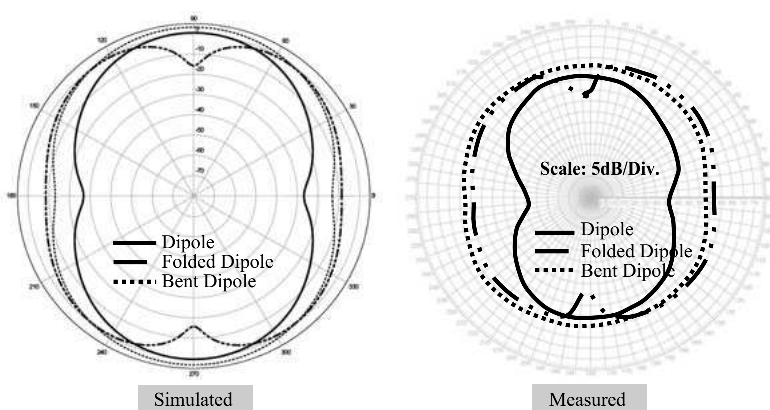
(e)


Dipole
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Simulated
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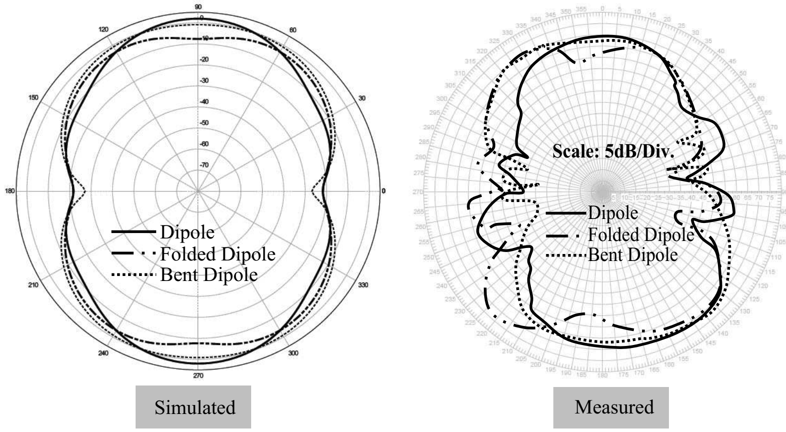
(f)



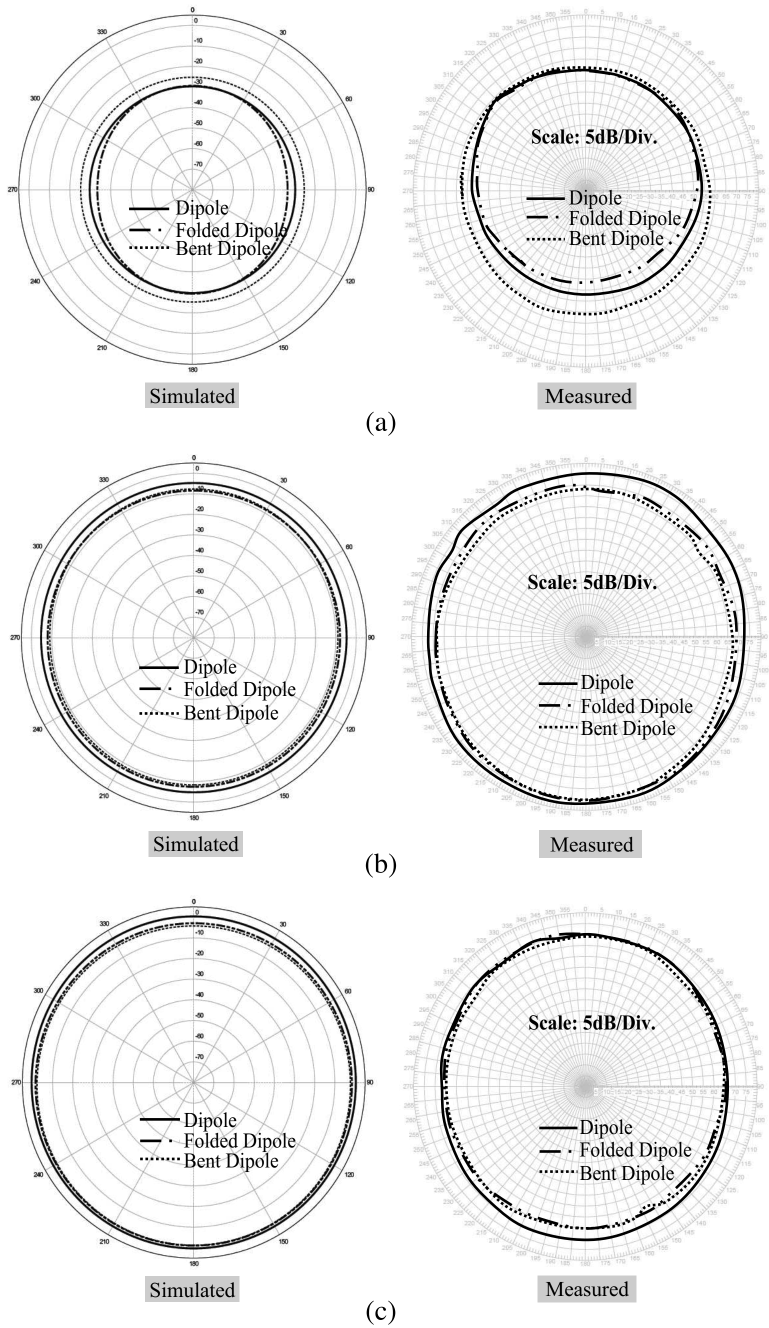
(g)

Figure 4. Simulated and measured E-plane radiation patterns of broadband dipole, folded dipole and bent dipole antennas. (a) Frequency: 100 MHz. (b) Frequency: 300 MHz. (c) Frequency: 500 MHz. (d) Frequency: 700 MHz. (e) Frequency: 800 MHz. (f) Frequency: 900 MHz. (g) Frequency: 1000 MHz.

frequencies (100–250 MHz) due it more electrical length. In frequency band 280–560 MHz, dipole gain is better, in 600–960 MHz again bent dipole performs better in terms of gain and higher band (above 960 MHz) dipole shows better gain. Over the entire frequency band (100–1000 MHz) dipole antenna shows consistently well defined radiation patterns. Folded and bent dipoles show null filled radiation patterns at most of the frequencies causing wastage of power in other directions and hence lesser gain at horizon at these frequencies. This can be attributed to the two factors:

1) Current distribution: For fat antenna elements (less λ/D ratio) the current at antenna ends is more compared to elements with larger λ/D ratio. This current provides an appreciable radiation from antenna ends.
2) Larger electrical separation of two conductors: In fat antenna elements configuration, the effective (lesser length/width ratio) electrical separation of two conductors is more causing appreciable in phase radiation from the antenna ends.

At higher band edge (900–1000 MHz) folded dipole shows pattern split with a null depth of 15 dB from beam maxima. This is because the electrical length of antenna at these frequencies becomes double


Dipole
Folded Dipole
Bent Dipole
Scale: 5dB/Div.
Simulated
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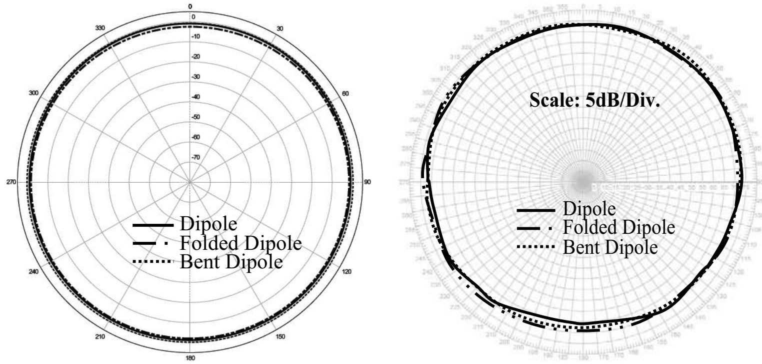
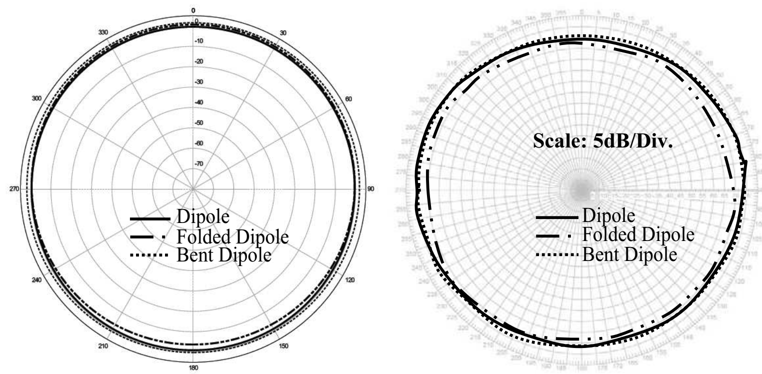


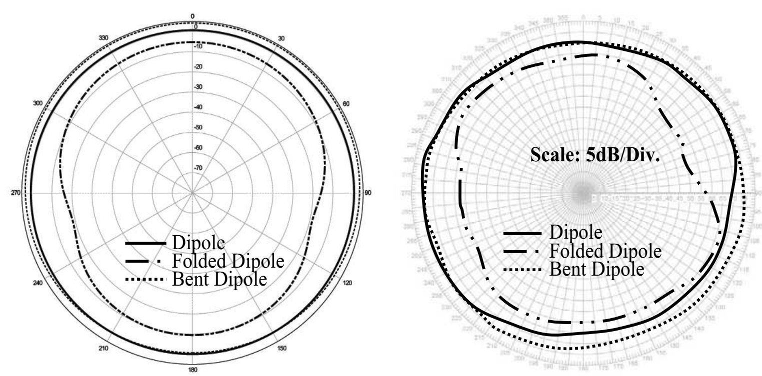
Simulated Measured

(d)



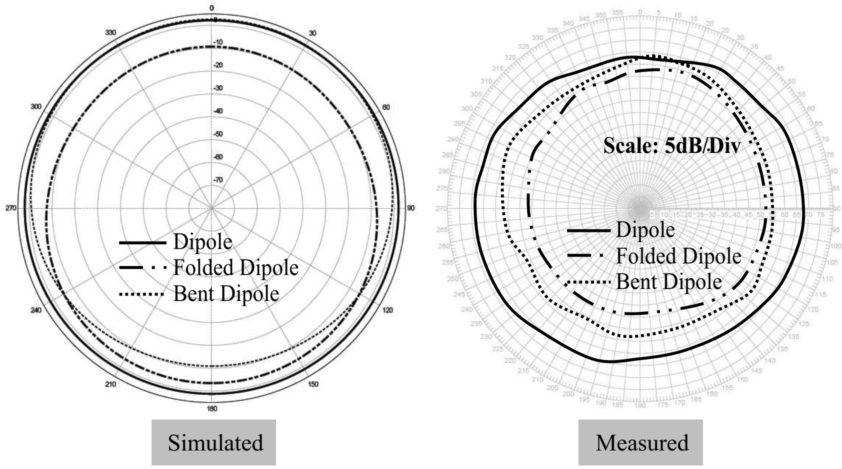
Simulated Measured

(e)



Simulated Measured

(f)



(g)

Figure 5. Simulated and measured H-plane radiation patterns of broadband dipole, folded dipole and bent dipole antennas. (a) Frequency: 100 MHz. (b) Frequency: 300 MHz. (c) Frequency: 500 MHz. (d) Frequency: 700 MHz. (e) Frequency: 800 MHz. (f) Frequency: 900 MHz. (g) Frequency: 1000 MHz.

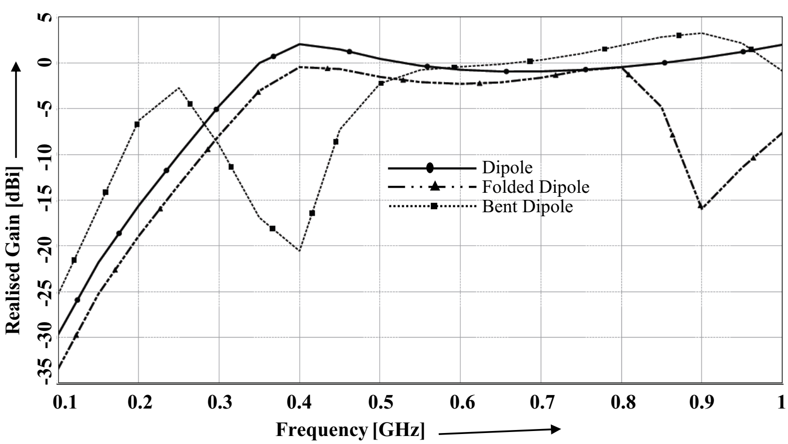


Figure 6. Simulated gain comparison of broadband dipole, folded dipole and bent dipole antennas.

of its resonant frequency and the folded dipole does not accept power (behaves as transmission line) at its even harmonics.

4. CONCLUSIONS

Three different antenna configurations have been designed and developed. Broad bandwidth is achieved with same impedance matching network for all. Impedance bandwidth for all three configurations is similar. At lower frequencies bent dipole is better option. In multi-octave bandwidth design, dipole antenna is the only option as it performs consistently better than its counterparts folded dipole and bent dipole.

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