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Wideband Blade Monopole Antenna with Sleeved Coaxial Feed

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***Abstract*— A wideband planar monopole antenna requiring a small ground plane is described. Numerical and measured results confirms the antenna has good radiation efficiency and stable omni-directional radiation patterns over an impedance bandwidth of 4.1:1 covering the 200-850 MHz frequency spectrum.**

I. INTRODUCTION

The monopole antenna is one of the most versatile antenna types used over frequencies ranging from HF to millimetre wave lengths. As is well known the impedance bandwidth of a thin monopole can be increased by modifying the wire element geometry, for example by thickening or meandering the wire element or adding material loading [1, 2]. Previous wideband monopoles that use such design techniques include the top-hat, ferrite and/or dielectric clad monopole, the discone and the caged monopole. These elements tend to be bulky and occupy a relatively large physical volume. Recently, planar monopole designs have been proposed that considerably reduce the volume of elements and have wideband impedance bandwidths [3, 4].

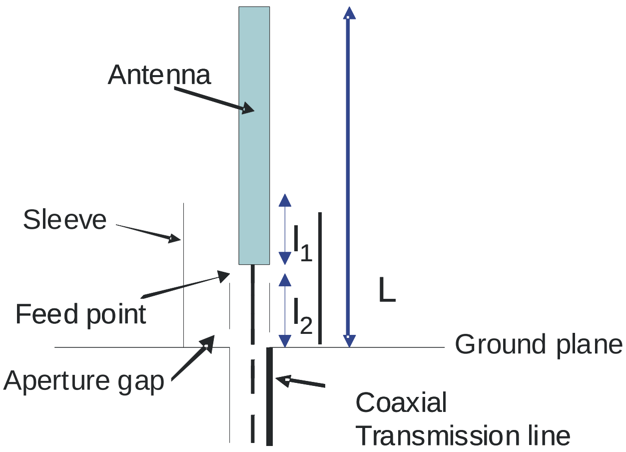

Fig. 1 Sleeved monopole antenna with elevated feed point [3].

In [5] an improved method of matching to the monopole element has been developed, and is shown in Fig. 1. Essentially the feed point of the monopole is elevated above its *own enclosed ground plane* and then enclosed by another outer cylindrical sleeve, so forming a coaxial line within a coaxial line. The outer coaxial line or sleeve is shorted to ground while the inner coaxial line is open circuited with an aperture near the ground. The radiating antenna that protrudes out of the enclosing sleeve is an extension of the centre conductor of the inner coaxial line. The total height of the monopole antenna is L and it resonates at $L \approx \lambda/4$, the lowest frequency. The coaxial transmission lines form a distributed two-pole tuned impedance transformer with the input impedance given as [6],

$$Z_{in} = Z_{01}\frac{Z_a + jZ_{01}\tan\beta l_1}{Z_{01} + jZ_a\tan\beta l_2} + jZ_{02}\tan\beta l_2 \qquad (1)$$

Where $\beta=2\pi/\lambda$ is the free space phase constant, Z_{01}, Z_{02} are the impedances of the coaxial transmission lines of length l_1 and l_2 respectively, and Z_a is the input impedance of the isolated monopole. Using this technique it is feasible to provide a match to a thin monopole over a 4:1 frequency range [10]. This paper reports a new form monopole antenna composed of the sleeved coaxial feed attached to a planar monopole. The antenna is capable of wideband operation with improved impedance and pattern bandwidth and requires little, or no, external ground plane.

II. ANTENNA DESIGN

The antennas design is broken down into two stages. Section A deals with the antenna design and characterisation in isolation. Section B examines integration of the antenna with the elevated coaxial feed and sleeve sections. The antennas impedance match and radiation patterns are examined on a range of different sized ground planes.

A. Blade Antenna

Planar broadband monopole design is based on the use of a number of primitive geometric shapes used either alone or in combination. Likely shapes included the bicone or bow-tie [7], square or rectangle [8], circle [3] and volcano or inverted cone shape [9]. The design principle is the same in all cases, for a fixed height to width each of these shapes can be scaled to provide the same bandwidth. Bandwidths of 5:1 up to 10:1 are feasible with a radiation pattern that is omni-directional in azimuth and single lobed in elevation. However, at higher frequency the radiation pattern shows perturbation since at these shorter wavelengths the antenna becomes electrically large. In this paper we use a novel tapered planar monopole geometry that resembles a “blade” shape. The blade is a combination of tapered rectangle and elliptical shapes, where the larger ellipse has been optimised to provide a wideband impedance transition with minimum mismatch. Fig. 2 shows a picture of the geometry and dimensions of the constructed blade monopole.

Fig. 3 shows the Ansoft HFSS simulated return loss for the blade antenna as a function of height above an infinite ground plane. It can be observed that the effect of increasing height is to enhance the impedance match. The optimum height was found from both simulation and measurement to be 13-15 mm. Fig. 4 shows a comparison of the measured and simulated S_{11} for the antenna over a smaller frequency range. The antenna was measured on an 80x80 cm square ground plane. The operating bandwidth of many antennas is typically defined as a VSWR of 2.0:1 with respect to 50Ω characteristics impedance, and on that basis the blade monopole bandwidth ranges from 400 MHz

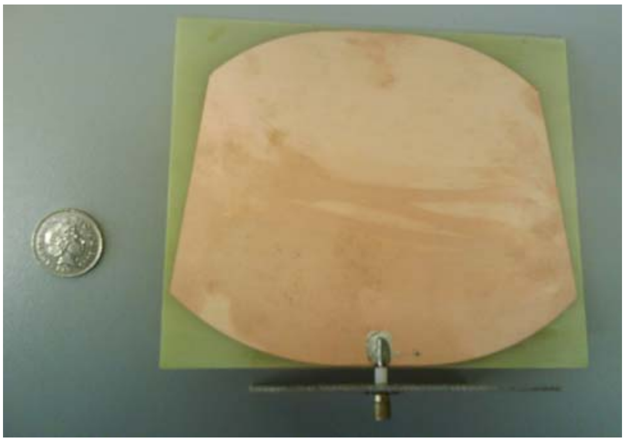

Fig. 2 Picture of the wideband blade monopole antenna (Dimensions: height =145 mm, width =166 mm, bevel angle 15º).

to a frequency in excess of 6.0 GHz (12:1 bandwidth). Note that the IEEE 802.11 standard sets more stringent impedance matched conditions and specifies the antenna VSWR to be less than 1.5:1. At the lower end of the operating band the antenna has a height of 0.20λ. The addition of the sleeved feed increases the total antenna height to ≈0.26λ.

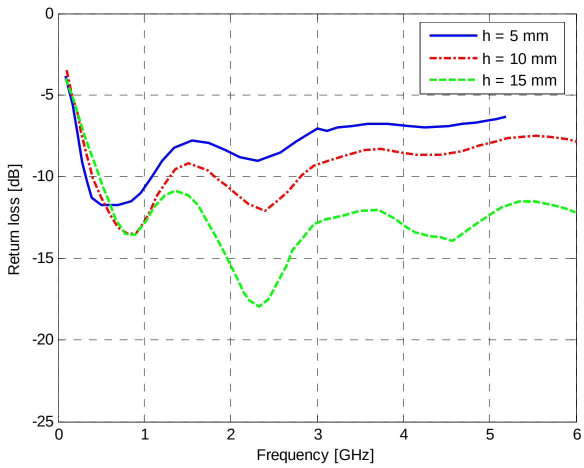

Fig. 3 Simulated and measured return loss for the blade monopole antenna as a function of height above the ground plane.

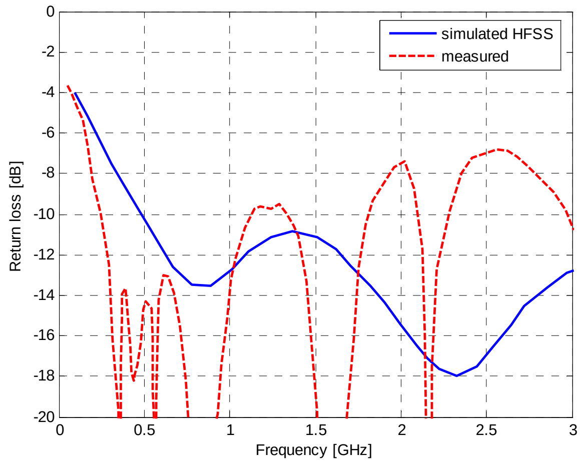

Fig. 4 Simulated and measured return loss for the blade monopole antenna on an 80x80 cm square ground plane.

B. Sleeved Coaxial Fed Blade Monopole

The antenna is attached to the sleeved and elevated coaxial feed section as shown in Fig. 1. The antenna protrudes 15 mm above the larger outer cylindrical metallic sleeve. A coaxial line impedance transformer of length l_1 composed of the outer conductor of the surrounded coaxial antenna feed line and the inner conductor of the cylindrical sleeve forms a short (λ/12) transformer of impedance $Z_{01} \approx 105\ \Omega$.

A coaxial line of length l_2 is formed from the inner conductor of the feed coaxial line and the sleeve making a transmission line of characteristic impedance $Z_{02} \approx 22\Omega$. A small annular aperture is cut on the outer conductor of the surrounded coaxial transmission line section, where the cable enters the ground plane so that the Z_{02} impedance forms a short circuited line. The height of the aperture was 1.5 mm and it primarily controls the bandwidth of the impedance match; the aperture height was optimised using Ansoft HFSS.

The assembled antenna is shown in Fig. 5. As discussed earlier the matched bandwidth of the sleeve design is much less than the impedance bandwidth of the blade monopole. Here we are interested in the overlap of the useable radiation pattern bandwidth combined the bandwidth over which the sleeve mitigates the use of a ground plane.

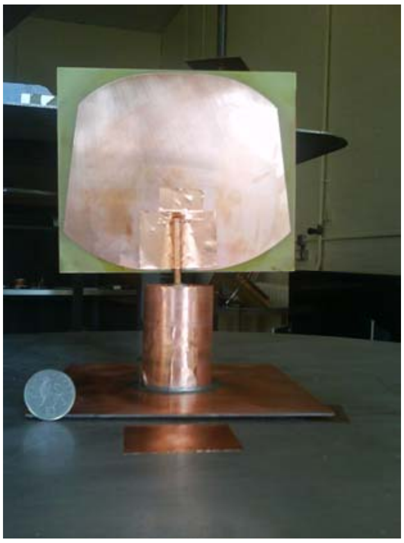

Fig. 5 Picture of the wideband blade monopole antenna with sleeved coaxial feed (dimensions: inner pin diameter =5 mm, inner coax diameter = 20 mm, sleeve diameter = 30 mm, sleeve height = 50 mm).

The impedance and radiation properties of the antenna have been examined by measurements and numerical experiments using HFSS. Fig. 6 shows the measured and analytically calculated, using Eq. 1, return loss for the antenna on a truncated ground plane of 5x5 cm sq. The measured return loss for the antenna on ground planes of larger sizes are also shown in Fig. 7. The effect of increasing the ground plane size on the antennas impedance matched bandwidth is minimal. Increasing the ground plane size acts to suppress resonances in the return loss. The VSWR is nearly less that 1.5:1 over a 4:1 bandwidth. This suggests that the sleeve feed is screening the antenna properties from its external environment. The accompanying poster will illustrate that the field structure over the external conducting sleeve remain almost frequency invariant over the desired antenna operating bandwidth.

III. Radiation Patterns

The radiation patterns for the antenna were simulated in both the principal H and E planes and are shown in Figs. 8 and 9, respectively. The radiated fields are consistent with physical intuition having an omni-directional pattern in the horizontal plane and a single null in the elevation plane. Fig. 10 shows the measured radiation patterns for the antenna in the horizontal plane at 500MHz on different sizes of ground plane. The fields were measured at an outdoor range and calibrated using a standard dipole. The measured field patterns are consistent with simulations although there is a slight perturbation at one angle. This anomaly was due to the setup of the outdoor measurement environment. The radiated fields where measured across the entire operating band 220-900 MHz and the patterns where found to maintain stable omni-directional performance. This is in contrast to other reported planar wideband monopoles feed on large ground planes were pattern instability (and impedance mismatch) become apparent with increasing frequency. The realised antenna gain which includes losses was also measured and simulated for a number of frequencies and is given in Table 1.

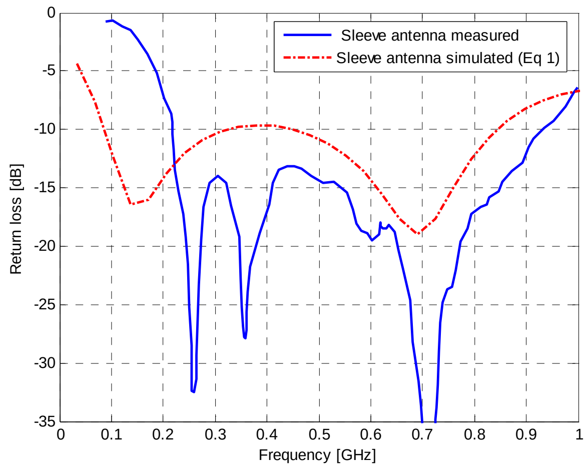

Fig. 6 Measured and simulated return loss for the antenna on a finite sized ground plane of 50x50 mm.

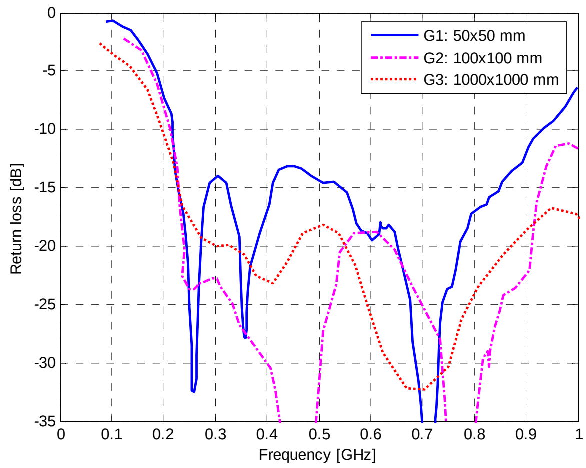

Fig. 7 The measured return loss for the antenna on ground planes G1, G2 and G3 of increasing size.

TABLE 1 REALISED GAIN OF SLEEVED BLADE MONOPOLE

Frequency [MHz]	Realised gain [dBi]	
	Measured (±1 dBi)	Simulated
250	3.0	2.0
500	3.5	3.5
750	5.0	4.7

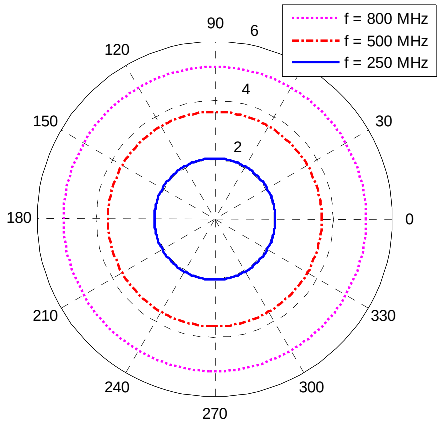

Fig. 8 Radiation patterns simulated for the antenna in the E_θ component of the H-plane (2 dBi/div).

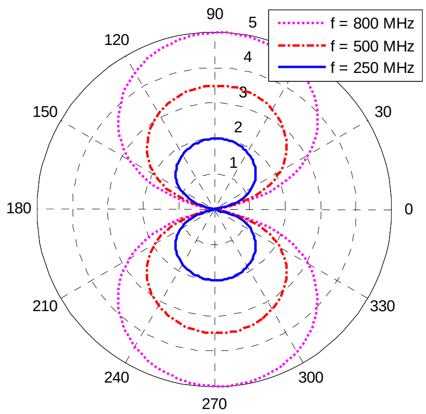

Fig. 9 Radiation patterns simulated for the antenna in the E_θ component of the E-plane (1 dBi/div).

IV. CONCLUSIONS

A wideband planar monopole antenna is presented combining a planar blade and novel sleeved coaxial feed transmission line. The antenna was simulated and measured with reasonable agreement. The sleeved feed enables the antenna to operate on very limited size ground planes. The antenna has a wideband 4:1 impedance matched bandwidth with omni-directional pattern in the azimuth plane and is dipole like in elevation. The antenna is intended for easy installation on a variety of platforms where minimum perturbations to impedance and radiation pattern performance are the foremost requirements.

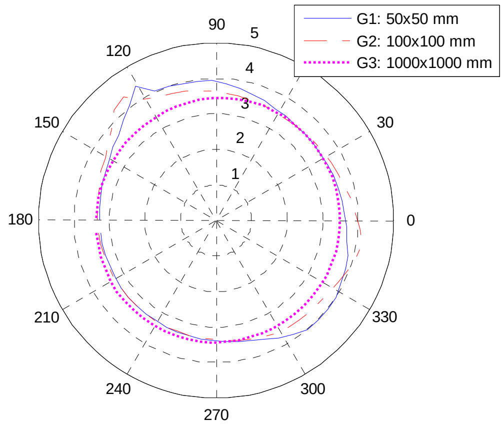

Fig. 10 Measured radiation pattern of the antenna E_θ component of the H-plane at 500 MHz with different ground plane sizes G1, G2 and G3 (1 dBi/div).

ACKNOWLEDGMENT

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