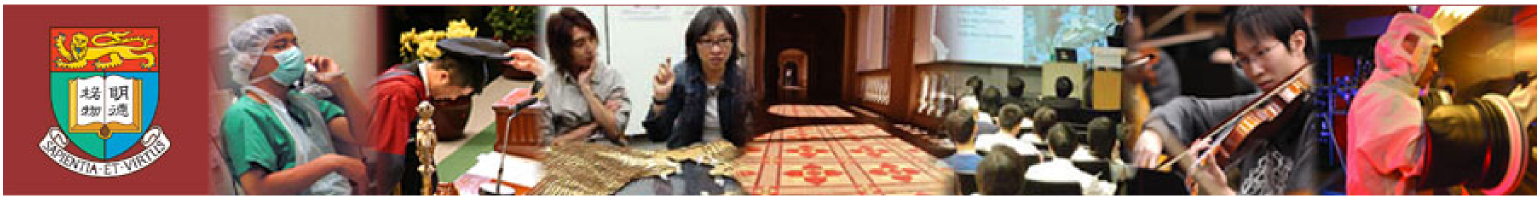

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Modeling of cable for measurements of small monopole antennas

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Abstract— **Coaxial cable is often used for measurements of antennas inside anechoic chambers. In the measurement of a monopole antenna with a small ground-plane, the finite-sized ground causes the current to flow back from the radiator to the outer surface of the coaxial cable. This results in secondary radiation which introduces errors to the measured radiation pattern. To reduce the unwanted secondary radiation, the coaxial cable can be covered with EMI suppressant tubing materials. However, this introduces errors to the measured efficiency. In this paper, the models of the coaxial cable with and without suppressant tubing are developed and used for computer simulation. The cable effects on the measured results of a small monopole ultrawide band (UWB) antenna are studied by using the antenna measurement equipment Satimo StarLab and the EM simulation tool CST. The results show great agreements between the simulated and measured results.**

I. INTRODUCTION

In the designs of antennas for modern wireless devices, the physical size is one of the important requirements to be considered. In the design of monopole antennas using the planar technology, one of the effective ways to reduce the overall size is to employ a small ground.

Different methods can be used to reduce the sizes of ground planes for monopole antennas, yet maintaining good performances [1]-[4]. In the design process of these small antennas, the performances in terms of impedance bandwidth, gain, return loss, radiation patterns and efficiency, can be optimised using computer simulation. However, when these antennas are implemented and then measured inside an anechoic chamber using an antenna measurement equipment, the performances very often do not agree with the simulation results, particularly at low frequencies [5][6]. The reason is that, in computer simulation, the signal is fed directly to the input port of the antenna. While in measurements, a coaxial cable with the appropriate connector (e.g. SMA connector) is inevitably used to connect the antenna with the measurement equipment. The signal from the Vector Network Analyser (VNA) is then fed to the antenna via the cable.

In such measurement setup, the cable can affect the radiation characteristics of the antenna in two possible ways. Firstly, since the cable is placed in the near-field region of the antenna, it will scatter or reflect the fields emitted from the radiator of the antenna, and thus affecting the radiation characteristics. Secondly, if the ground plane of the small antenna is made electrically small, it cannot be approximated as having an infinite size. Some current will flow back to the outer surface of the cable, causing radiation from the cable [7]. Therefore, in the designs of monopole antennas with small ground planes using computer simulation, ignoring the cable effects will result in serious discrepancies between the simulated and measured results.

Several methods have been used to reduce the cable effects. One of the methods is to place a quarter-wavelength sleeve on the surface of the cable right below the connector to provide an open end at the edge of the antenna [8][9]. However, the sleeve can only operate at one single frequency, so the method is for narrow-band applications. Dual-band baluns have been designed to prevent the current from leaking back to the cable [10]-[12]. These baluns again have narrow bandwidths which restrict their uses in wideband antennas. Putting ferrite beads on the cable can also be used to absorb the unwanted radiation approaching to and from the cable [13]. This method could have a wideband usage, but it affects the radiated power and so causes inaccurate measurements on radiation pattern and efficiency. An effective method for wideband applications is to employ EMI suppressant tubing around the cable to absorb the spurious radiation [14].

In this paper, the effects of cable on the measurements of a small planar ultrawide band (UWB) monopole antenna are studied using computer simulation and measurement. A

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coaxial cable with an SMA connector is modelled using CST. The cable effects with and without suppressant tubing are studied using the model developed. The antenna is measured using the antenna measurement equipment, Satimo StarLab, with the results compared to the simulation results. With the use of the model developed for the coaxial cable, simulation results show good agreements with the measurement results.

II. ANTENNA FOR STUDIES

The planar monopole UWB antenna used in [6] is selected for our investigation of cable effects. The antenna consists of an elliptical radiator fed by a 50-Ω microstrip line on one side of the substrate and a small rectangular ground plane with a size of $gl \times gw$ = 30 mm×30 mm on the other side of the substrate, as shown in Fig. 1 [6]. The substrate used is Rogers RO4350B, having a relative dielectric constant ε_r = 3.48, a thickness 0.762 mm and a loss tangent 0.0037. The dimensions of the antenna are optimized in terms of impedance bandwidth by computer simulation. The width of the microstrip line is linearly tapered from w_1 to w_2 to achieve good impedance matching. The distance, *gap*, between the elliptical radiator and the upper edge of the ground is also critical for impedance matching and so needs to be optimized as well. Table 1 lists the optimized dimensions of the antenna which has also been fabricated on a Rogers PCB, RO4305B, as shown in Fig. 2 [6].

III. CABLE EFFECTS ON ANTENNA EFFICIENCY

The simulated return loss and radiation efficiency of the antenna, without the cable attached, are shown in Fig. 3. The return loss and efficiency of the prototyped antenna are measured using the antenna measurement equipment, Satimo StarLab, and shown in Fig. 4. Of course, a coaxial cable with an SMA connector attached to the antenna, as shown in Fig. 5, is inevitably needed for measurement using the Starlab equipment. The coaxial cable is provided by Satimo for use with Starlab and is covered with EMI suppressant tubing to absorb radiation. The measured results are also shown in Fig. 3 for comparison.

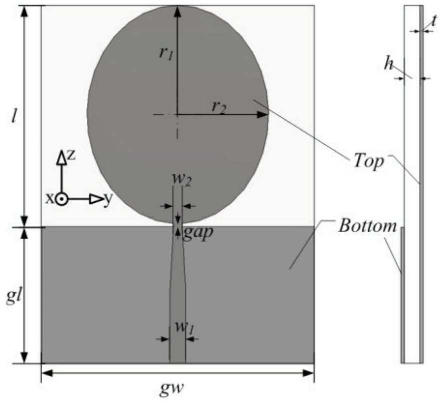
It can be seen that the measured efficiency is much lower than the simulated efficiency at the frequencies below 8 GHz. The simulated and measured efficiencies have better agreements at higher frequencies. This is because, at lower frequencies, the ground-plane size is electrically small compared with the wavelength. When the antenna is connected to the coaxial cable for measurement, the current flows back to the outer surface of the coaxial cable, resulting in unwanted radiation. This unwanted radiation is absorbed by EMI suppressant tubing around the cable and does not get radiated and so cannot be measured by the equipment. As a result, the measured efficiency is much lower than that of the simulated efficiency.

At higher frequencies, the wavelength becomes relatively smaller. The ground plane becomes electrically larger and has a better approximation to infinite size. Only little current flows back to the coaxial cable, so the cable has less effect on the measured results.

IV. MODEL OF CABLE

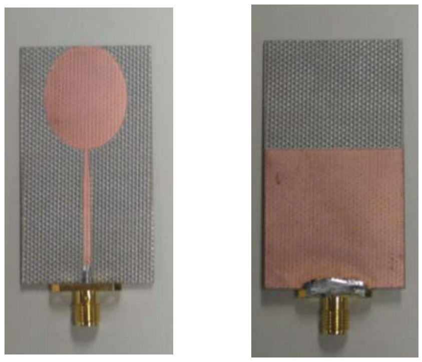
To better understand the effects of the cable on measurements, the coaxial cable with an SMA connector is modelled using the CST. The simulation model of the cable is shown in Fig. 6, with dimensions listed in Table II. A metallic brick with a size of 6.5 mm × 6.5 mm × 13.5 mm is placed below the feed line to model the SMA connector. The inner conductor of the cable has a radius of 0.45 mm. The outer conductor has an inner radius of 1.5 mm and an outer radius of 1.8 mm. The dielectric Teflon with a permittivity of 2.08 is used to fill the space between the inner and outer conductors. The cable length used for simulation is 200 mm.

Simulation using the CST on the current distributions at a lower frequency of 3 GHz and higher frequency of 8 GHz has been carried out. Results have shown that, at the frequency of 3 GHz, a large amount of current is flowing on the outer surface of the cable, which would result in radiation. While at the frequency of 8 GHz, the current on the outer surface of the cable is much smaller, thus the cable has much smaller effects on measurement. This explains the reason for the relatively good agreements between the simulated and measured efficiencies at high frequencies shown in Fig. 3.



(a) (b)

Fig. 1 Layout of UWB antenna: (a) top view and (b) side view



(a) (b)

Fig. 2 Photograph of UWB antenna: (a) top view and (b) bottom view

TABLE I
ANTENNA DIMENSIONS

Parameter	***Value(mm)***	***Parameter***	***Value(mm)***
gl	30	*gw*	30
h	0.762	*t*	0.035
l	24.3	*gap*	0.3
r_1	12	r_2	9.5
w_1	1.73	w_2	0.6

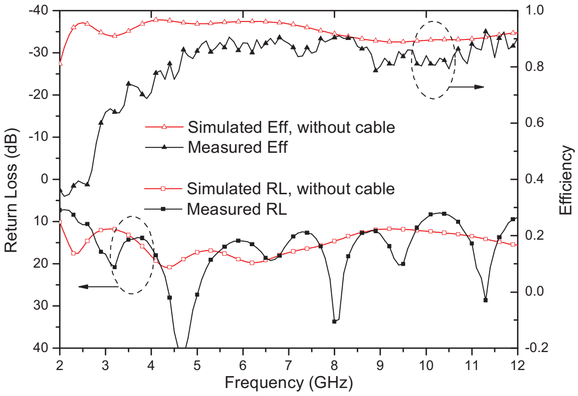


Fig. 3 Simulated and measured return losses and efficiencies

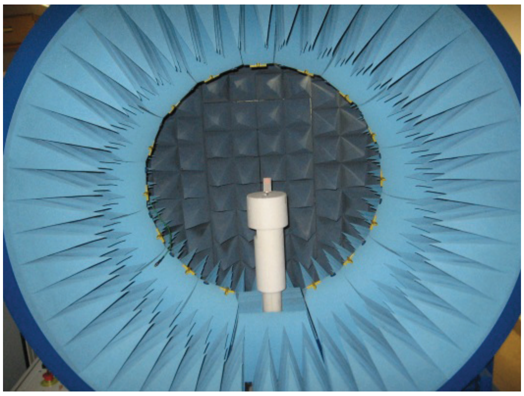


Fig. 4 Antenna in StarLab for measurement

Fig. 5 Prototype Antenna with coaxial cable

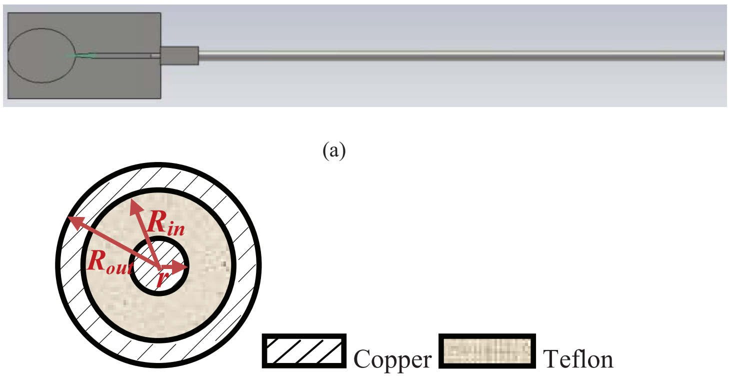


Fig. 6 Simulation model with cable: (a) CST model and (b) cross section of cable

TABLE II
CABLE DIMENSION USED IN SIMULATION (UNIT: MM)

R	R_{in}	R_{out}
Radius of inner conductor	Inner radius of outer conductor	Outer radius of outer conductor
0.45	1.5	1.8

V. EFFECTS OF EMI SUPPRESSANT TUBING ON CABLE

The coaxial cable provided by Satimo for antenna measurement is covered with EMI suppressant tubing to absorb unwanted radiation. To take into account the effects caused by EMI suppressant tubing, we also model the suppressant tubing layer in simulation. Fig. 7 shows the simulation model of the coaxial cable with EMI suppressant tubing. The tubing layer has a thickness of 1.25 mm, permittivity of 5-j0.02, and permeability of 5-j2.5 at 6 GHz. Although the actual cable used in the equipment is quite long, a length of 200 mm is used in simulation. Without the use of the cable, it takes about 10 mins in simulation using HP Pro 3130 MT business PC. While with the use of the 200-mm cable, it takes about 2 hours.

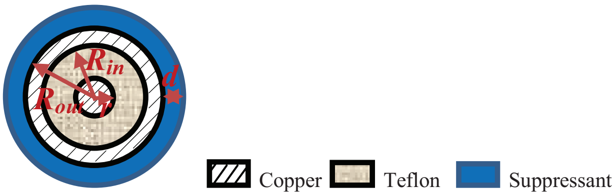


Fig. 7 Cross section of the cable with suppressant tubing

Fig. 8 shows the simulated efficiency with the inclusion of the cable model and the measured efficiency. It can be seen that, when using the suppressant tubing model in simulation, the simulation and measurement results show high consistency. This means that our simplified model can effectively be used to represent the Satimo's measurement system.

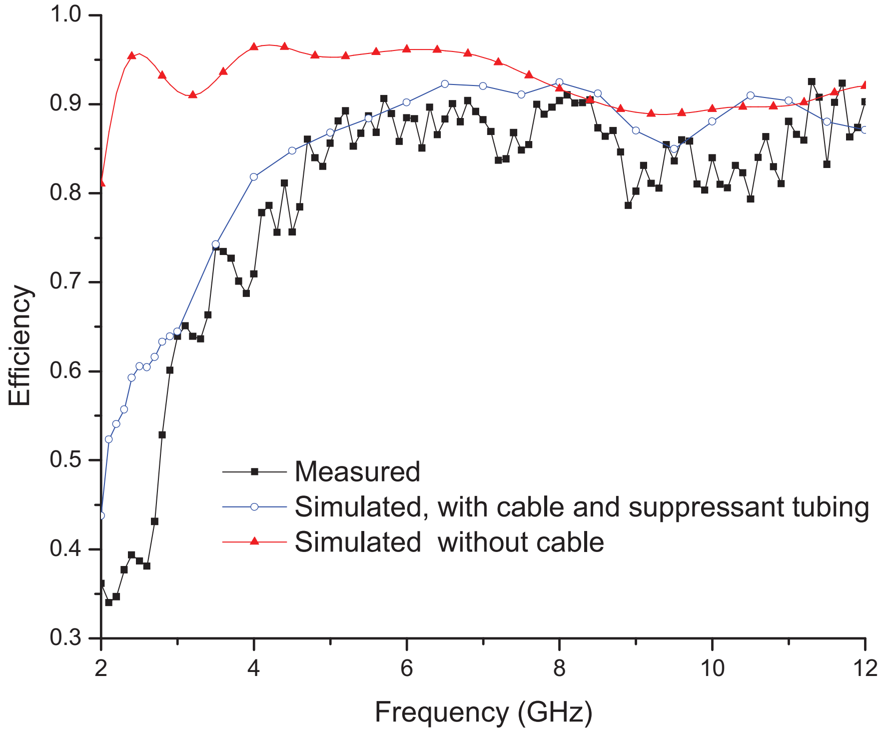


Fig. 8 Simulated and measured efficiencies

VI. CONCLUSIONS

The model of the coaxial cable with and without suppressant tubing used for antenna measurements have been developed in CST and used for simulation. The cable effects with and without suppressant tubing on the measurements of a planar monopole UWB antenna have been studied using computer simulation. Results have shown that, with the use of the cable model developed, there are good agreements between the simulated and measured radiation efficiencies.

REFERENCES

[1] S. W. Cheung, L. Liu, R. Azim, and Mohammad T. Islam, “A Compact Circular-Ring Antenna for Ultra-Wideband Applications,” *Microwave and Optical Technology Letters*

[2] L. Liu, T. I. Yuk and S. W. Cheung, "Bandwidth Improvements Using Ground Slots for Compact UWB Microstrip-fed Antennas," *Progress In Electromagnetics Research Symposium* (*PIERS*) *2011*. Suzhou, China, 12-16 September, 2011

[3] K. Ki-Hak and P. Seong-Ook, "Analysis of the small band-rejected antenna with the parasitic strip for UWB," *Antennas and Propagation, IEEE Transactions on,* vol. 54, pp. 1688-1692, 2006.

[4] J. Jihak, C. Wooyoung, and C. Jaehoon, "A small wideband microstrip-fed monopole antenna," *Microwave and Wireless Components Letters, IEEE,* vol. 15, pp. 703-705, 2005.

[5] Y. F. Weng, S. W. Cheung and T. I. Yuk, “Triple Band-Notched UWB Antenna using Meandered Ground Stubs”, *Loughborough Antennas & Propagation Conference*, 8-9 November 2010, Loughborough, (LAPC 2010), UK

[6] Y. F. Weng, S. W. Cheung and T. I. Yuk, “Effects of Ground-Plane Size on Planar UWB Monopole Antenna” *International technical conference of IEEE Region 10 (Tencon2010)*, November 21-24, 2010, Japan

[7] C. Icheln, “Methods for measuring RF radiation properties of small antennas,” PhD thesis, Helsinki University of Technology, Espoo, Finland, Nov. 2001.

[8] S. A. Saario, J. W. Lu, and D. V. Thiel, "Full-wave analysis of choking characteristics of sleeve balun on coaxial cables," *Electronics Letters,* vol. 38, pp. 304-305, 2002.

[9] Y. L. Chow, K. F. Tsang, and C. N. Wong, "An accurate method to measure the antenna impedance of a portable radio," *Microwave and Optical Technology Letters,* vol. 23, pp. 349-352, 1999.

[10] C. W. Hsue, Y. C. Lin, and K. L. Chen, "Dual-band baluns for reducing the influence of feed cable in antenna measurement," *Microwave and Optical Technology Letters,* vol. 50, pp. 1000-1004, 2008.

[11] C. Icheln, J. Krogerus, and P. Vainikainen, "Use of balun chokes in small-antenna radiation measurements," *Instrumentation and Measurement, IEEE Transactions on,* vol. 53, pp. 498-506, 2004.

[12] C. Icheln and P. Vainikainen, "Dual-frequency balun to decrease influence of RF feed cables in small antenna measurements," *Electronics Letters,* vol. 36, pp. 1760-1761, 2000.

[13] S. Saario, D. V. Thiel, J. W. Lu, and S. G. O'Keefe, "An assessment of cable radiation effects on mobile communications antenna measurements," in *Antennas and Propagation Society International Symposium, 1997. IEEE., 1997 Digest*, 1997, pp. 550-553 vol.1.

[14] The capcon website. [Online]. Available: http://www.capconemi.com/supressant_tubing.pdf