Design Details for the 2017 Taiwan Creative Electromagnetic Implementation Competition

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Abstract—This paper describes the reason we chose the coaxial cable as our main structure and the materials we used to implement proposed scheme. In addition, this paper outlines some theoretical backgrounds as well as the measurement results. This design won the 2nd prize in the 2017 Taiwan Creative Electromagnetic Implementation Competition.

I. Introduction

This paper describes the design we came up with for the 2017 Taiwan Creative Electromagnetic Implementation Competition (T-CEIC). The objective for this competition is to devise and implement an electromagnetic structure longer than 2.5 meters with minimum loss when operated at 3 GHz. We designed and constructed a coaxial cable using commonplace stationeries and achieved a loss of approximately 7.4dB.

II. Comparison Among Potential Schemes

The competition states no restriction on whether the transmission medium should be wired or wireless. Thus we took different approaches, both wired and wireless, into consideration. According to Friis transmission equation showed below,

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi R)^2}, \tag{1}$$

where P_r and P_t are the power at the receiving antenna and output of transmitting antenna, G_r and G_t are the gain of the receiving antenna and transmitting antenna, λ is the wavelength of the transmitted signal and R is the distance between receiving and transmitting antennas, the loss between two antennas placed 2.5 meters apart is about 50dB.

However, when consulting specifications of coaxial cables, we discovered that many coaxial cables achieves a loss of less than 12dB per 100 ft. at 3GHz [1], which translates into about 1dB loss per 2.5 meters. Considering the difficulty and precision required to produce an antenna that achieves 25 dB gain, we opt for the coaxial cable as the main structure for the competition.

III. Structure, Material and Dimension

A typical coaxial cable consists of center conductor, dielectric, outer shield and outer jacket. Specifications of low loss coaxial cables[1] reveal that stranded center conductors show superior loss performance over solid center conductor. Thus, we selected stranded copper wires as the center conductor and used straws to help maintaining rigidity of the wire. Also, like many extremely low loss coaxial cables which use air as the dielectric with the assistance of spacers to hold the center conductor in place and prevent it from touching the outer shield, we used air as dielectric and made spacers out of thick cardboards. The cardboards were cut into small squares and we punched a hole in the center of each square, allowing the center conductor to go through. This assembly was then fitted inside the thicker straws. Finally, copper tape, serving as the outer shield, were put on the outside of the larger straws. We also tried to add copper braids or aluminum shields to the outer shield, but we measured no significant benefits by doing so. The outer jack was omitted since protection and insulation from the environment were of little concern.

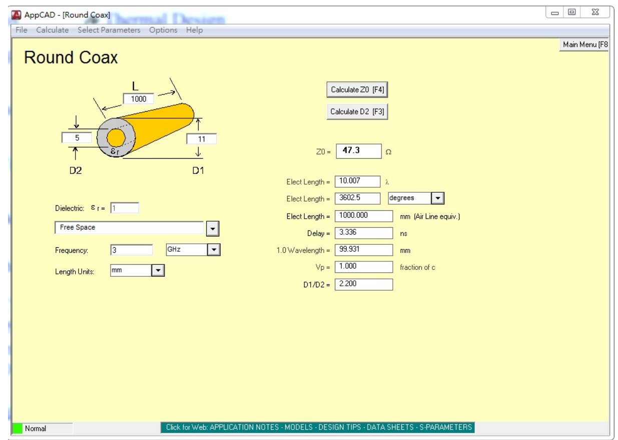


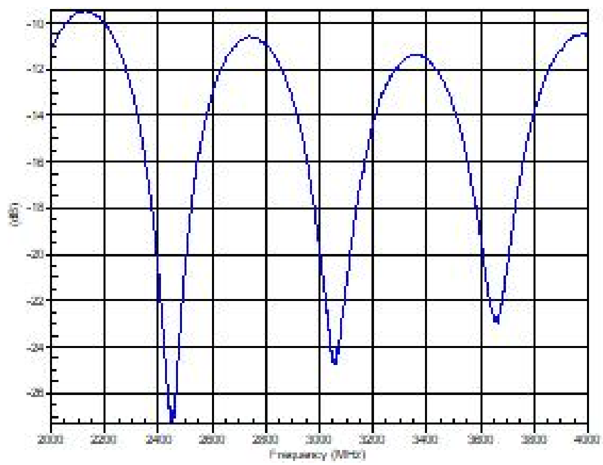
Fig. 1: Theoretical impedance of coaxial with dimension proposed.

The impedance of a coaxial cable depends on diameter ratio between the inner conductor and the outer shield,

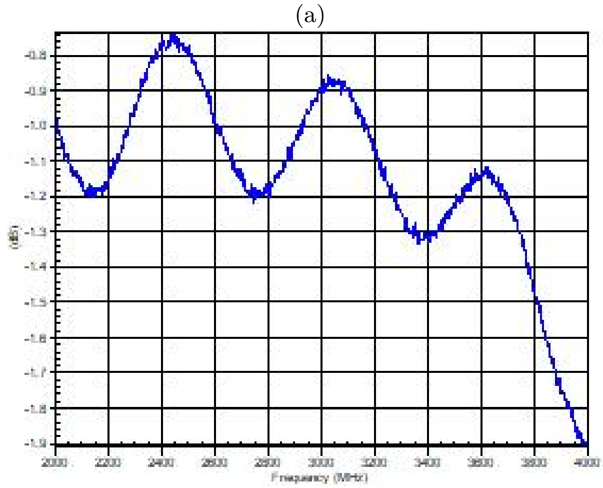
$$Z_0 = \frac{1}{2\pi}\sqrt{\frac{\mu}{\epsilon}} \ln\left(\frac{D}{d}\right) \approx \frac{60}{\epsilon_r} \ln\left(\frac{D}{d}\right) (\Omega), \tag{2}$$

where d and D are diameters of inner conductor and outer shield.

The diameters of the thinner straw and the thicker straws are 5 millimeter and 11 millimeter, respectively. This dimension has an impedance of 47.3 Ω [2], and thus it should match 50 Ω equipments well. Fig. 1 show the simulation of theoretical impedance. However, due



(a)



(b)

Fig. 2: Reflection coefficients of (a) S_{11} and (b) S_{21}.

to the use of stranded center conductors, the impedance measured is observed to be a bit lower than the theoretical value.

IV. Prototype and Competition Results

A. Prototype

We prototyped a short-length version (20 cm) of the proposed scheme and measured the S_{11} and S_{21} parameters using a vector network analyzer, which are shown respectively in Fig. 2.

We see that the proposed scheme exhibits reasonably low reflection and a loss of about 0.9 dB.

B. Competition Results

We designed and constructed a coaxial cable using commonplace stationeries and achieved a loss of approximately 7.4dB. Eventually, we came in the second prize in the 2017 Taiwan Creative Electromagnetic Implementation Competition.

References

[1] RF Microwave Coaxial Cable. Harbour Industries, VA. [Online]. Available: http://harbourind.com/harbourdev/images/prod_cat_catalogs/Coax_Catalog.pdf

[2] AppCad. Avago Technologies. [Online]. Available: http://www.hp.woodshot.com/