# G_High_gain_CP_Antenna_MICEEI_2014r.pdf

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# High Gain CP Antenna for Mobile Satellite Communications Numerically Evaluated under Various Packaging Materials

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***Abstract*—The designed CP microstrip antenna suitable for mobile satellite communication was numerically evaluated using various packaging materials. The study is important to provide sufficient information regarding the electrical properties variations of the constructed antenna in the presence of the shielded media. Those worthwhile characterizations are essentially required on the final packaging stage of the whole antenna unit and electronics circuits as an integrated communication peripheral. The numerical evaluation is very useful to be carried-out in order to select the appropriate shielded cover. Based on the computation results, in free space, the antenna has large gain 16.5 dBi and excellent impedance matching at S-Band (2 – 4 GHz) to provide the large operation bandwidth approximately 1900 MHz. As the antenna system shielded using various plastics box cover there are significant alterations on the targeted electrical properties such as the reflection constant ($S_{11}$), the impedance bandwidth, axial ratio (AR), and gain. While mobile satellite terminal, consisted of antenna unit and various electronics parts, was enclosed with the polyester, polycarbonate and polyvinylchloride (PVC) of the plastic packaging materials types, the overall gain and bandwidth achieved were 4 dBi and 1600 MHz (spans on the frequency range from 1.5 GHz to 3.1 GHz), respectively. Meanwhile, the gain and bandwidth are also altering as ABS (polyacrylonitrile), polypropylene and polyethylene used. These three protective cover materials also affect the alteration of both bandwidth and gain of the mobile satellite antenna. The two parameters, i.e. bandwidth and gain, altered to approximately 1 GHz (at the frequency resonances 2.5 – 3.5 GHz) and 4 – 10 dBi, respectively.**

***Keywords:* *CP antenna, Mobile satellite, Broadband communication and S-Band application***

## I. INTRODUCTION

The utilization of the broadband mobile satellite communication has experienced significant improvement as the demand of the large transferred data capacity increased. One of the alternative technology solutions to accommodate that trend potential market is the availability of the mobile satellite services to connect the remote area, for instance the islands and mountainous regions, to the global ICT network. The future development of mobile satellite peripherals undergoes to be low profile, compact, easy on designing and manufacturing and inexpensive production, operation and maintenance costs.

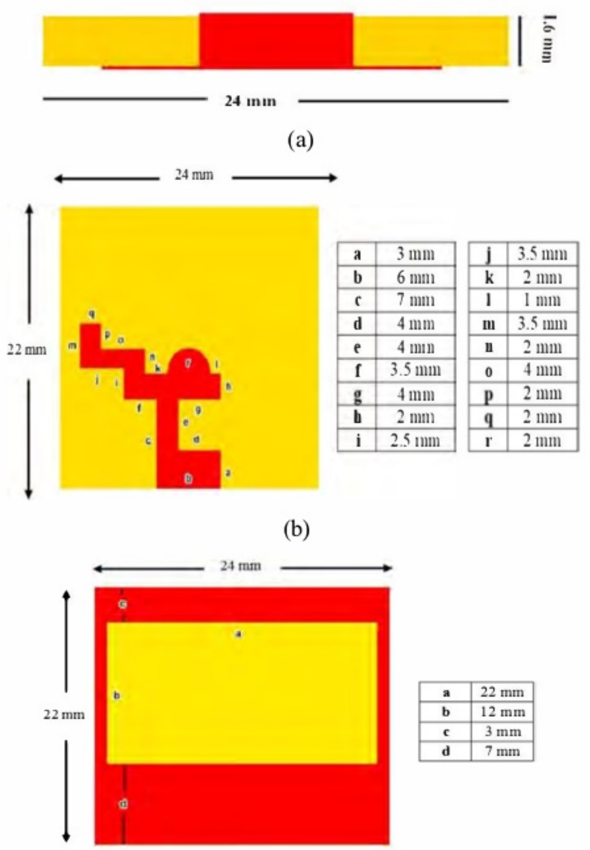
Various applications could take the benefit of the mobile satellite system advantageous. These include the vehicle unit, train system, airplane system, satellite broadcasting system, marine application, other aeronautics systems, and land communication applications [1- 4]. The whole performance of the constructed mobile satellite system is in practical determined by a number of parameters including the antenna physical structure created; the circuit design configured; the electronic parts soldered and incorporated; and the packaging technology applied. Some of the most influencing factors are very interesting and challenging to study further.

This paper mainly focuses the intensive discussion on the effect on using various different shielded cover (the packaging materials) of a mobile satellite unit. Considering the intended technical requirements such as portable, compact and user friendly, on the mobile terminal construction therefore the antenna and the electronics circuits assembled have to be performed in a proper way. To address those issues, the studies of the designed antenna system and the corresponding physical printed circuit configuration play the important part to characterize the certain performance to be achieved. For a long range communication distance application the common antenna design is preferable to have the circular polarization (CP) property [2-7]. The kind of antenna is a low profile and has very excellent performance in terms of gain and axial ratio (AR). In practical application, CP antenna role is suitable to address various environmental phenomena such as the multipath fading, Faraday rotation, rain depolarization, and any other depolarization phenomena while the signals propagating from one transmitter side to another receiver [8]. In actual mobile communication applications such as the satellite networking, there is no fix orientation between the transmission and the reception parts in terms of the wave propagation directions. The waves propagate to any directions and are highly possible to arrive at the receiver from any random directions. To maintain the quality of the signals reception to stay in very excellent power levels, the important role of CP antenna construction is very crucial part.

## II. MOBILE SATELLITE ANTENNA MODELING

### A. *Antena Structure and Principle Operation*

The antenna model constructed to suitable for the S-Band mobile communication application is illustrated in Fig.1. To meet the IEEE standard regarding RF wave practical use and policy, the antenna was developed to operate at the frequency range of 2 – 4 GHz.




| | | | |
|---|---|---|---|
| a | 3 mm | j | 3.5 mm |
| b | 6 mm | k | 2 mm |
| c | 7 mm | l | 1 mm |
| d | 4 mm | m | 3.5 mm |
| e | 4 mm | n | 2 mm |
| f | 3.5 mm | o | 4 mm |
| g | 4 mm | p | 2 mm |
| h | 2 mm | q | 2 mm |
| i | 2.5 mm | r | 2 mm |

| | |
|---|---|
| a | 22 mm |
| b | 12 mm |
| c | 3 mm |
| d | 7 mm |

Figure 1. Antenna Structure (a) side view (b) top view (radiating layer) (c) bottom view (grounding layer)

Basically, the antenna structure has been designed to fit a particular physical size of mobile satellite communication device. The numerical size of the antenna is 24 x 22 x 1.6 mm (see Figure 1). The structure of the antenna itself consists of three different materials to form the patch structure, i.e. the dielectric layer (FR4-Epoxy), the tiny top and bottom conducting layers (tiny layers of the printed cupper material on both surface of the dielectric). As the common technical operation, in the transmit mode, the top conducting layer radiates RF power that injected from a RF transceiver. However, in the receiving mode, this part captures RF waves propagating from many directions on the proximity of wireless transceiver environment itself. A 50 Ohm SMA connector was considered to attach on one side of the patch structure and configured as the *edge feeding* RF-port.

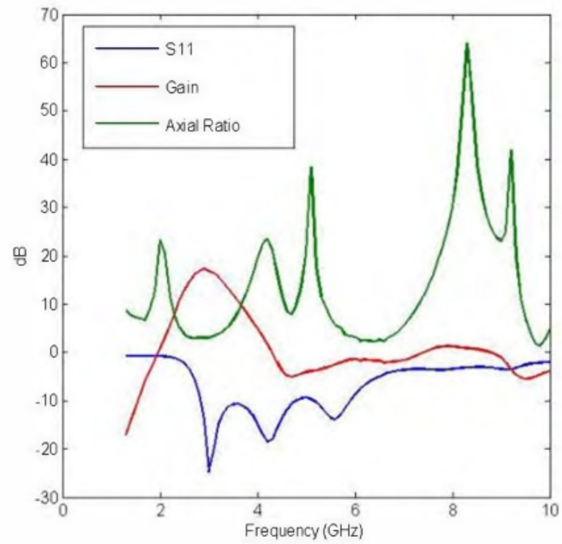



Figure 2. Performance of the designed high gain CP mobile satellite antenna in Free Space

Figure 2 above presents three main electrical characteristics of the constructed mobile satellite antenna, i.e. the reflection coefficient ($S_{11}$), gain and the axial ratio ($A_R$). The antenna has very broad operation frequencies ranging from 2.8 – 4.7 GHz and the impedance matching profile was excellent on that frequency range. The impedance bandwidth is more or less 1.9 GHz. The large gain of more than 16 dBi can be achieved while the antenna operated at the frequency 3 GHz. In this case, the antenna performs the circular polarization mode where its axial ratio is very close to 3 dB.

### B. *Impact of Using Various Different Shielded Plastic Materials*

On the early stage of investigation, the antenna has been designed and simulated by considering an air media as the radiation boundary. The computation result exhibits an excellent bandwidth at the frequency range of 2.8 - 4.7 GHz. The antenna model is then simulated by replacing boundary with plastic material. The simulation results obtained that the electrical properties altering significantly. The antenna design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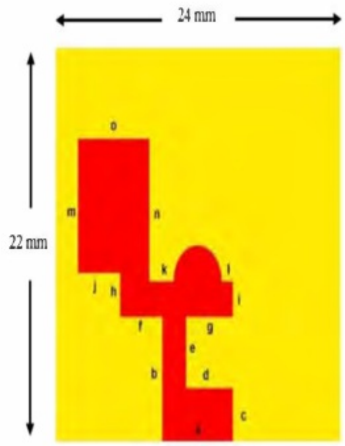
was optimized later on through the numerical computation and the final physical size of some parts of the patch structure generated as shown in Figure 3. The antenna is further examined by replacing the boundary radiation with various plastic materials and recording the outcomes variations. Variations in the value of $S_{11}$ as the function of the antenna operating frequency shielded using various types of plastic materials (ABS, polyester, polycarbonate, polypropylene, PVC and polyethylene) are illustrated in Figure 4.




| | |
|---|---|
| a | 6 mm |
| b | 7 mm |
| c | 3 mm |
| d | 4 mm |
| e | 4 mm |
| f | 3.5 mm |
| g | 4 mm |
| h | 2.5 mm |

| | |
|---|---|
| i | 2 mm |
| j | 3.5 mm |
| k | 2 mm |
| l | 1 mm |
| m | 7.5 mm |
| n | 6 mm |
| o | 8 mm |

Figure 3. An optimised dimensions of the antenna top radiating element

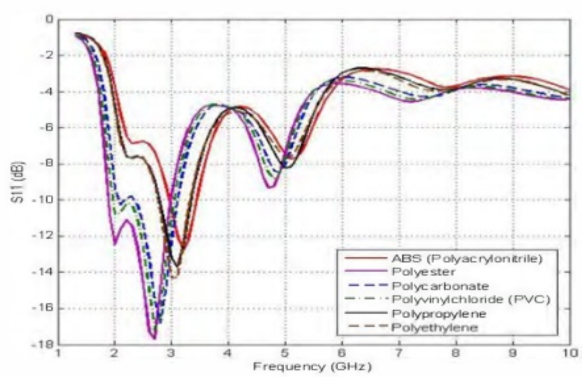



Figure 4. The Reflection Coeficients of Varieties Plastic Cover

Figure 4 above very clearly describes the impact of using various different plastic materials as the protective shielding on the antenna electrical properties. Three plastic materials used, i.e. polyester, PVC and polycarbonate, effect to the shifting of the antenna frequency operation to the band of 2-3 GHz. Even though, the three materials have a dielectric characteristic almost the same with the value of permittivity 2.8 - 3.2, however, one should note that the use of polyester has the ability to reflect electromagnetic waves much bigger. Other materials such as ABS, polypropylene and polyethylene shielded on the antenna system performed very good operation at the frequency band of 2.5 - 3.5 GHz. This three materials have the same value of permittivity is between 2 - 2.25 and the reflection coefficient is better than the previous material that having a larger permittivity. Amongst the other three materials category $S_{11}$ while using polyethylene has better characteristic than others. As the antenna numerical model implemented using HFSS software was imported into CST software the significant alterations occurred on the resonant frequency and the reflection constant ($S_{11}$). The antenna will work better at 4 GHz.

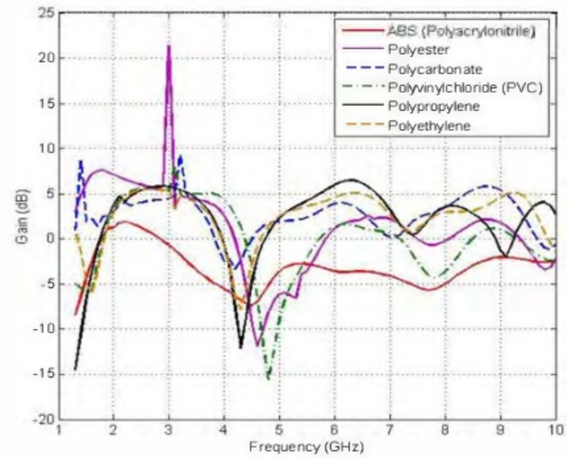



Figure 5. Antenna Gain Comparison for Various Plastic Cover

The radiation pattern radiated from the antenna is good enough, where the gain obtained about 3-6 dBi while using shielded materials constructed from polycarbonate, PVC, polypropylene, and polyethylene. Polyester material has a gain characteristic is much higher than the other. The value is more or less 22 dBi at a frequency of 3 GHz. Those results while verified using CST program, the numerical gain achieved was approximately 5-7 dBi.

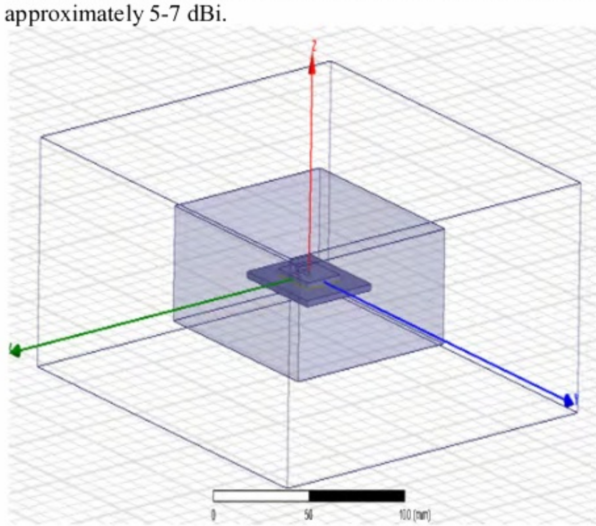


Figure 6. Two PCB Elements Stacked inside Mobile Satelitte Terminal Box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## III. Experiments and Evaluations of Designed Mobile Satellite Antenna

The antenna performance of the mobile satellite terminal is influenced by the structure of the shielding material. In this simulation model of the terminal design was performed by using Ansoft HFSS v1. It was considered that mobile terminal consisted of an antenna unit, electronic circuits and terminal box. Electronic circuits composed of PCB FR4_epoxy material with dimensions 44 x 48 x 1.6 mm and placed underneath the antenna design plate. This was configured just like arranging two stacked plate layers. Both were placed together inside the box that is assumed as the mobile satellite casing box. The box dimension was about 100 x 100 x 30 mm.

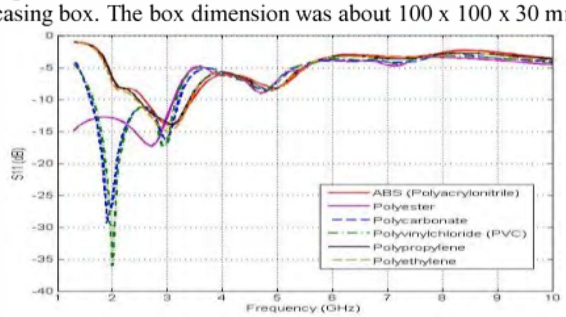
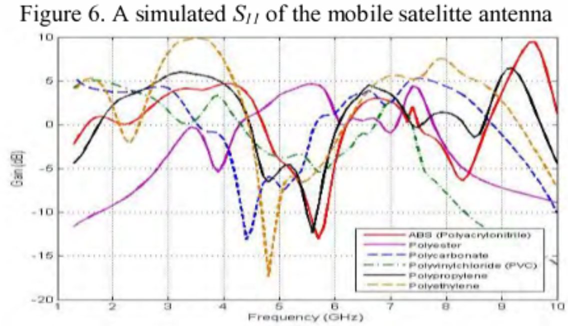



Figure 6. A simulated $S_{11}$ of the mobile satelitte antenna




Figur 7. The antena gain alterations as the casing box material of mobile satelitte terminal varied.

It is obviously based on Fig.6 that polyester, polycarbonate and PVC have the same effect on the reflection constant characteristics alterations while used as the protective shield. These materials used can influence the practical operation of the whole mobile satellite device and the frequency operation shifted to the frequency range of 1.5 - 3.1 GHz. Amongst the three materials, PVC produces a better reflection coefficient which is about -36 dB at 2 GHz. While using polyester material, the best reflection coefficient level can be achieved approximately -17.5 dB at a resonance frequency of 2.8 GHz. Moreover for material ABS, polypropylene and polyethylene used as a terminal casing, respectively will have almost the same effect on the alteration of both the impedance bandwidth (1000 MHz) and the reflection constant (-14 dB) at the frequency of 3 GHz.

It is obviously that by considering a certain operation frequency range (between 2.5 - 3.5 GHz) when polycarbante and polyester materials used as shielded cover of mobile satellite terminal the recorded gain looks relatively stable at 4 dBi. Meanwhile, a polyethylene one used the most excellent was obtained approximately 10 dBi. However, as other materials used such as polypropylene and ABS the recorded gain achieved were 7 dBi and 4 dBi, respectively.

## IV. Concluding Remarks

The designed microstrip patch antenna of the high gain 16.5 dBi was presented. The constructed antenna was capable to operate in the circular polarization mode at the frequency operation of 2.8 - 4.7 GHz. The antenna performance was numerically evaluated through the modeling of the mobile satelitte communication terminal. In practical computation the constructed antenna was placed inside a casing box composed various plastic materials. The simulation results show that the polyester, polycarbonate and polyvinylchloride (PVC) which has a relative permittivity of 2.8 - 3.2 maintain the antenna operation in the frequency range 1.5 - 3.1 GHz ($S_{11}$ <-10 dB). The average total gain is approximately 4 dBi. While ABS (polyacrylonitrile), polypropylene and polyethylene materials used as a casing the operation frequency of the satellite terminals were slightly alter to 2.5 - 3.5 GHz. The average total gain produced were slightly less than 4 dBi, 7 dBi and 10 dBi, respectively.

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