Multilayer electromagnetic wave absorber by a dielectric material in direct to home system

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Abstract. The satellite is the one which plays a vital role in the medium of satellite dishes for television, communication, internet and most important role in military application. The solution for this problem occur in the satellite dish used for television is discussed here. Whenever the development is done by taking the technology as medium and smart innovative work are done, at last it has some disadvantage which finally occurs as a problem that is changes in meteorological conditions leads to disconnection of the signal. Although a renowned parabolic reflector is there, it gets shattered before reaching the receiver due to the cold rain weather condition. The method and material proposed here will be able to overcome the problem occurred.

Keywords: Satellite dish, Parabolic reflector, Dielectric material, EM waves

1. Introduction

An artificial radiant light that revolve around the star, sun and also numerous planets with an extremely high velocity emitting a Electromagnetic(EM) waves at a inexact momentum of 30,00,000 km/s which is literally a speed of light. This renowned gigantic entity is entitled as a satellite. At present, individuals are accustomed that universe is jam packed with natural satellite. The requirement of artificial satellites should be clarified. The response for this query is conversed here. An ultimate satellite has many applications but the major gain is it also unites the people in remote areas with communication networks like television, telephones, internet etc. In India satellite dish system operators are employing satellites owned by the foreign countries for the purpose of up linking systems and down linking system. The transponders of Kurz Above (KA) band is widely applied here. Generally, KA band has the capability to provide data in very high speed [1].

The material which is used must be less in weight. The antenna dish has to be built in such a way that it should have higher strength and the polymer layer used should be very thin and light [2-4]. EM waves interference is a major drawback here. EM waves interference faults usually results in incorrect operations of devices. Before reaching the convertor the signals from the dish is decoded with help of the digital receiver. The diameter of the parabolic dish is mostly around 42 to 80cm. The reflector is designed and set in a position where the EM waves are trapped accurately [5-8]. Usually EM waves have variations in frequency and wavelength. The EM waves with high frequency have less wavelength and EM waves with less frequency have high frequency. The velocity of the waves are directly proportional to frequency and wavelength.
Figure 1. Breakage of Electromagnetic Waves

The key relevance is satellites are broadly expanded in satellite dishes which are frequently used in Direct to Home (DTH) systems. But there are some obstacles too. During worst weather condition the electromagnetic waves which are absorbed by the parabolic reflector and reflected back to the Low Noise Block down converter (LNB) gets interrupted. The reasons for the breakage of these EM waves is clarified. There are specific phenomenon which is the foremost trouble for this problem. They are absorption and scattering of energy by the material medium like fog, snow, rainfall and rough weather conditions. Due to these aspects the EM lose their frequency and parabolic reflector tends to obtain EM waves with a diminished amount of frequency. Figure 1.explains the EM waves breakage during the changes in the meteorological condition. Water precipitations during rainfall has the capability to affect the EM waves with very extreme frequency of and above 10 Giga Hertz (GHz). Television dishes has the proficiency to collect only less frequency of 1 GHz. So signals are simply lost.

It is a well known fact that EM waves comprise of photons with transfer of energy. A partial amount of energy gets absorbed by the water dew and degenerate in the form of heat and other half of the energy gets scattered in the atmosphere. The material used here has good electrical and chemical properties. EM waves usually cannot be absorbed by an ordinary object. Distribution of EM takes place in the form of refraction, reflection and diffraction. A finest dielectric material Silicon Carbide (SiC) is used to overcome this problem [9-12]. In the Figure 2. Shows how the satellite signals from broadcast station to the television.
2. Constituents and operations

The parabolic reflector is formulated with a fiber glass on which the aluminium is layered. The aluminium is largely used for reflecting the EM waves to the receiver. Since sun is a natural satellite. It also radiates definite amount of ultra violet radiation. Some amount of calcium carbonate and catalyst are assorted with aluminium and plastered on the film of polyethylene to prevent the absorption of Ultraviolet (UV) rays. The dish should be positioned in such a way that its latitude and longitude must be around 49 and 20 respectively. The reflector must be between the size of 6 to 18 inches.

In Figure 3, the parts of the DTH receiver is shown. The LNB is a combinational network consists of intermediate frequency amplifier, local oscillator and frequency mixer. The “probe” which is fixed inside the LNB helps to align the signal polarization. The diameter of the LNB’s top portion is must be around 40mm. In the figure 4, the EM signals sent by the broadcast system reaches the LNB receiver and travels through the each of the LNB and finally reached the television.

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Figure 4. Process chart for signal processing

Figure 5. Interior of LNB
2.1 Feedhorn
In the figure 5 the interior parts of the LNB is clearly shown. Feed horn has the paramount competency to absorb the incoming signal established by the LNB. At this instant the polarization process takes place gradually and attenuated. The polarized signals obtained here are directed to the probe where the frequency is measured precisely. The signal is in the form of direct current. The frequency acquired is of nearly 10 Mega Hertz (MHz). The diameter and length of the probe should be around 16mm and 15mm correspondingly. The probe is typically fixed perpendicular to the direction of natural light i.e sun. Then comes the superior waveguide, it usually guides the waves to stream in a particular direction mostly in a single direction and the loss of signal gets minimized to an extremely small amount. Printed Circuit Board (PCB) is the most vital element in the LNB because it delivers the electrical and mechanical support to the components inside LNB. PCB provides tracks to the incoming signal.

2.2 Conversion of signals from Digital to Analog
The LNB converts the incoming EM waves which collide on the surface from higher to lower frequency. This transformed frequency flows by the means of coaxial cable and also supplies a smaller amount of attenuation. The frequency attained from the local oscillator in the internal part of LNB and the delivered signals with appropriate quantity of frequency co join to produce an intermediate frequency of about 950MHz to 1450MHz. The local oscillator operates in such a way that it yields spare frequency of 50MHz than that of incoming frequency.

3. Absorption
The EM waves which incident on a surface is divided into three types. They are transmitted waves, absorbed waves and reflected waves. Consider a material having two media 1 and 2. When an incident wave with a appropriate frequency hits on medium 1 it gets incident through the medium 2 and electric field (E) is produced. There is some magnetic flux (H) developed around the medium 1.

Incident EM waves at state line:

In the figure 6 the incident waves are passed from one medium 1 to medium 2 is mentioned.

Figure6. Incident EM waves

Electric field at incident EM wave is given by,

\[ \mathbf{E}_{\text{incidence}} = \hat{a}E_0e^{j\omega t} \]  

(1)
Magnetic field at incident EM wave is given by

\[ \vec{H}_{\text{incidence}} = \frac{1}{\eta_1} \vec{E}_{\text{incidence}} \times \vec{E}_{\text{incidence}} = \frac{A}{B} \frac{1}{\eta_2} \vec{E}_i e^{-j\omega t} \]  

(2)

Where,

\[ \eta_1 = \frac{1}{\omega (\varepsilon_1 \mu_1)^{\frac{1}{2}}} \quad \text{(} \varepsilon_1 \text{ is a constant)} \quad \eta_2 = \left( \frac{\eta_1}{\eta_2} \right)^{\frac{1}{2}} \]

Reflected EM waves at state line:

Figure 7 shows, the reflected waves are passed from medium 2 to medium 1.

\[ \vec{E}_{\text{reflection}} = \vec{E}_r e^{j\beta t} \]  

(3)

Magnetic field at reflected EM wave is given by,

\[ \vec{H}_{\text{reflection}} = \frac{1}{\eta_2} (-\vec{E}) \times \vec{E}_{\text{reflection}} = \frac{1}{\eta_2} \vec{E}_r e^{-j\beta t} \]  

(4)

Reflection coefficient = \[\frac{E_r}{E_i}\]

Transmitted EM waves at state line:
Electric field at transmitted EM wave is given by,

$$\mathbf{E}_{\text{transmitted}} = \mathbf{\hat{n}} E_0 e^{-jnm_2}$$  \hspace{1cm} (5)

Magnetic field at transmitted EM wave is given by,

$$\mathbf{H}_{\text{transmitted}} = \frac{1}{j\eta_2} (\mathbf{\hat{n}} \times \mathbf{E}_{\text{transmitted}})
= \frac{\mathbf{\hat{n}}_2}{n_2} E_0 e^{-jnm_2}$$  \hspace{1cm} (6)

Where,

$$n_2 = \omega (\varepsilon_2 \mu_2)^{\frac{1}{2}}$$

$$\eta_2 = \left( \frac{n_2}{\varepsilon_2} \right)^{\frac{1}{2}}$$

Transmission coefficient $$= \frac{E_2}{E_0}$$

Reflection and Transmission of EM at state lines in medium 1

$$\mathbf{E}_1 = \mathbf{E}_{\text{incidence}} + \mathbf{E}_{\text{reflection}}
= \mathbf{\hat{n}} \left( E_0 e^{+jnm_2} - E_0 e^{-jnm_2} \right)$$  \hspace{1cm} (7)

$$\mathbf{H}_1 = \mathbf{H}_{\text{incidence}} + \mathbf{H}_{\text{reflection}}
= \frac{\mathbf{\hat{n}}}{n_1} \left( \varepsilon_0 e^{+jnm_2} + \varepsilon_0 e^{-jnm_2} \right)$$  \hspace{1cm} (8)

Reflection and Transmission of EM waves at state lines in medium 2

$$\mathbf{E}_2 = \mathbf{E}_{\text{transmitted}}
= \mathbf{\hat{n}} E_0 e^{-jnm_2}$$

$$\mathbf{H}_1 = \mathbf{H}_{\text{reflection}}
= -\frac{\mathbf{\hat{n}}}{n_2} E_0 e^{+jnm_2}$$  \hspace{1cm} (9)

Reflection of EM waves at state line:

In the figure 8 the transmitted waves are passed from medium 1 to medium 2. This transmitted wave is go to the LNB receiver.
Figure 8. Transmitted EM waves

\[ \vec{E}_1(a=0) - \vec{E}_2(a=0) \]
\[ \Rightarrow \vec{E}_b + \vec{E}_b = \vec{E}_b \]
\[ \vec{H}_1(a=0) = \vec{H}_2(a=0) \]

\[ \eta = \left( \frac{1}{\varepsilon} \right) \frac{1}{a} \]

Reflection coefficient
\[ r = \frac{E_b}{E_b} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \]

Transmission coefficient
\[ t = \frac{E_b}{E_b} = \frac{2\eta_1}{\eta_2 + \eta_1} \]

Reflectivity of dielectrics,
\[ r = \frac{(\varepsilon_1)^{\frac{1}{2}} - (\varepsilon_2)^{\frac{1}{2}}}{(\varepsilon_1)^{\frac{1}{2}} + (\varepsilon_2)^{\frac{1}{2}}} \]

Reflection of EM at the state line:
\[ r = \frac{E_b}{E_b} \]
\[ r = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \]
3.1 Qualities of a Suitable absorber
The EM wave absorbing material should possess some properties such as cost efficient, weight of the material must be low, it should resists the chemical and thermal conductance. It should be proficient to withstand harsh circumstances like rough weather, lightning and rainfall. The material should act as an interference shielding. The waves must be absorbed properly and should not be radiated. The impedance in free space and absorbing material should be matched equally. The impedance level should be checked to know how much amount of standing wave is controlled. The material should possess strong magnetism in order to transmit the incident way properly. There is a dielectric material which satisfies these properties much better than aluminium which is actually used in DTH as a absorbing material. The tremendous material used here is silicon carbide.

4. Silicon carbide (SiC)
The unknown fact is silicon carbide is completely an insulator when it is present in its purest form. The bonds present in the silicon carbide are very hard-wearing and rigid. In the Figure 9, the structure of SiC is shown. The SiC comprises of silicon and carbon with tetrahedral structure. It is transformed into a dielectric material with supreme properties by doping and fluctuating its morphological structure. The N type semiconductor of SiC is made by doping the elements like nitrogen (N) and phosphorous (P). On the other hand the p type semiconductor of SiC is made by doping the rudiments such as Boron(B), Aluminium(Al), Beryllium(Be) and Gallium(Ga). It is evidently known that each silicon atom and carbon atom is surrounded by four silicon and carbon atom. The structure of the crystalline is closely packed. The hybridization of SiC is SP³. Due to the tightly arrange structure the thermal and electrical properties are very much contented. Due to these morphological characters this material acts not only as a good thermal resistance but also as a beneficial chemical resistance. This material has extremely low density of about 3.20g/cm². since it has very low concentration, the mass of the material is considerably low and has excessive porous property i.e many number of pores are present in SiC so that the absorption and multiple reflection takes place without risk and simultaneously.

![Figure 9. Structure of Silicon Carbide](image-url)
4.1 Divisions of EM absorption material

Type 1:

From the figure 10, it is well known that dielectric property and magnetic property has the huge impact on absorption. The absorbing material should be manufactured in such a way that the loss of dielectric and magnetic properties must be in a lesser amount. The chemical nature of the material should also be considered. Every single material undergoes chemical reaction within it. But an EM absorbing material should carry out the minimum chemical reaction. i.e chemical bonding of atoms must be negligible.

Figure 10. Properties in EM absorption

Type 2:

In type 2, different layers of the reflector are shown in the Figure 11. Absorbing materials includes three layers. They are impedance matching layer, attenuation layer and reflective layer. An impedance layer is fundamentally meant for permitting the incoming EM waves into the absorber with negligible surface reflection. Then comes the attenuation layer. It is vastly used for diminishing the attenuation loss by using the dielectric and magnetic materials. The concluding layer is reflective layer. Here the metal is used for improving the reflection of incoming signals.

Figure 11. Layers in the reflector
4.2 Impedance matching layer

To achieve the impedance layer a porous layer with a material which has high electrical conductivity is required. Impedance layer is mandatory for the appropriate absorption of Electromagnetic waves. The layer of SiC with a assortment of Silicon Oxide (SiO) is fabricated with cobalt oxide ($\text{Co}_x\text{O}_y$). The surface should be sheltered properly which can be achieved by shifting the mass of precursor. On this layer a coating of carbon is accomplished since it is a good conductive material. Cobalt oxide is an inorganic material which is highly employed in semiconductors. The role of SiO is it has the property to relocate the electric charges because of this impedance is increased. Permeability is also increased drastically when cobalt is used rather than using SiC in its purest form.

![Figure 12(a). Frequency Vs Permeability graph 1](image1)

![Figure 12(b). Frequency Vs Permeability graph 2](image2)
From the figure 12(a) and 12(b), it is clearly seen that when silicon carbide is utilized in its purest form frequency of the EM waves becomes constant. When it is amalgamated with elements like Co3O4 frequency is favourably boosted in significant amount. For the perfect matching of impedance the loss of reflection range must be less than -10dB (decibel). Perfect matching of impedance results in prominent absorption that is 90 percent of the EM waves are absorbed. The permeability $\mu' = 1$ and $\mu'' = 0$ which means there will be no magnetic loss. The absorption range has drastically increased from 12GHz to 18GHz. The efficiency of absorption increases slowly than the actual range when this alternate material is used.

4.3 Attenuation layer
Attenuation loss should be prevented for the improved absorption of EM waves. A porous and a hollow structure is fixed to minimize the attenuation loss and also to moderate the mass of the material. Material encompassing high porous property enhances high absorbing property. The material having elevated stacking fault comprises large number of pores which supports to absorb the maximum EM waves. Stacking fault is nothing but a crystal having discontinuous arrangement of planes. Due to the presence of stacking fault redistribution of electric charges is improved and high polarization is engendered. As the polarization is high EM waves misplaces its energy and readily absorbed by the porous layer. Porous nature can be boosted by using SiC porous nano composites. SiC is used here because it has huge stacking fault with tightly packed double layer. SiC porous nano composite solid is made by roasting it at the temperature of 400°C and placed in a layer of (Poly PYrrole) PPY nano films.

4.4. Porous layer.
In the given figure 13, the porous structure of the crystals is shown. These properties are much effective in enhancing the absorption. The absorption quality is increased up to 99%. Hence the loss of reflection is around -10dB. The EM waves are absorbed around the frequency of 11GHz to 19GHz. Due to the exhaustive polarization dielectric loss is increased hence results in the excellent absorption of the EM waves by the material.

Figure 13. Porous structure
Figure 14(a). Frequency Vs Permeability graph 3

The graph shown in figure 14(a) is plotted between real part of permeability and frequency in GHz. The value of permeability $\mu'$ should be greater than 1. Only then the EM waves are continuously absorbed by the porous layer completely. At this time, more than 90% of the waves are reabsorbed.

Figure 14(b). Frequency Vs Permeability graph 4

The figure 14(b) shown above is plotted between the imaginary part of the permeability ($\mu''$) and the frequency. Permeability ($\mu''$) should be exactly 0 which means magnetic loss is truncated. In this region 99% of the EM waves are absorbed completely. From the above 2 graphs it is clearly known that only 40% of the Sic porous nano composite is required.

4.4. Reflective layer
From the figure 15, it is shown that according to nature of foam the reflected waves are noted. Reflective layer is the one where the waves are reflected. A polished surface is usually spent for producing reflective layer. The surface must not be too heavy. Foaming materials are generally needed since the mass of the material is comparatively low; it is also a good absorbent and also more efficient. This layer enhances the polarization and multiple reflections simultaneously because of its better scattering effect. The proportion of the foam cell is very much lesser than the wavelength ($\lambda$) of incident electromagnetic waves. The compactness of the foam is 1.92 and its electrical conductivity is 2.25. The frequency is emitted about 4GHz to 17GHz. The output is the EM waves reflected properly even if the thickness of the EM waves is about 2mm to 6mm.

5. Results and future conclusion
Satellites are widely helpful in broadcast system such as television and mobile phones. Though satellites are more helpful in broadcasting still it has some disadvantages which is not irreparable. The errors will be in the form of breakage of EM waves during rough weather. In the above composition a new material is used which enhances the absorption property. In future, satellites will be widely used everywhere and broadcast system will play a vital role in signal processing. The material used here is more superior which possess all the properties what an ideal absorbing material has to possess. The efficiency of the satellite dish system is increased in a wide range. The material is designed in such a way that the absorption and reflection of frequency will not be stopped even at the rough weather. Future world will be more dependent on satellite communications. It would be operated from global infrastructure.

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