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THE ROLE OF SOLAR FLUX IN COMMUNICATION

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ABSTRACT

Although there is a vast advancement in technology, it is impossible to stop natural disasters, but we can prevent the extent of human and heritage loss with proper communicative measures. Devices like HAM Radios works even if no power is available on VHF & UHF frequencies i.e. from 30MHz—3000MHz. This paper enhances the use of solar power for effective communication and considering ionosphere which plays a key role in enhancing Radio frequency. The formation of sunspots and solar flares increases solar radiation to a great extent. As ionization effect increases, radio communication will be more effective. The amount of solar energy radiated per unit area is termed as Solar Flux.

Key words : *Solar flux*, *Sunspots, Solar Flares, Ionosphere, Communication, Ionization.*

1. INTRODUCTION

Our planet earth is surviving till today just because of Sun. Sun provides energy in all directions. When this energy reaches the earth's surface, it is called insolation. The radiation from Sun provides light energy and heat energy to Earth in the form of electromagnetic waves of which 99% have wavelengths are in the range of 0.2 to 0.4 micrometers. These waves may be ultraviolet rays, X rays, visible rays, infrared rays etc.. Solar energy reaching the top of the Earth's atmosphere consists of about 8% ultra violet radiation (short wavelength, less than 0.39 micrometers), 46% visible light (0.39 to 0.78 micrometers) and 46% infrared radiation (long wavelength more than0.78 micrometers) Solar radiation travels through the atmosphere, some of it is absorbed by the atmosphere (16%). Some of it is scattered to space (6%). Some of it is reflected by clouds (28%). About 47% of it reaches the Earth's surface.

2. TEMPERATURE ON THE SUN

The Sun is a huge sphere of glowing gasses that produce energy and light. Temperature on the sun is non uniform as shown in figure 1. It has different temperatures at different regions.The temperature of the Sun varies tremendously, and not in the ways we imagine. Sun' atmosphere consists of three main layers which are as follows:-

Photosphere:- The temperature on the photosphere of the Sun is about 10,000 degrees F (5,500 degrees C). It is here that the Sun's radiation is detected as sunlight. Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly
as dark spots compared to surrounding region. These regions are cooler compared to the surrounding area.The temperature at the center of the sunspot is as low as 7,300 degrees F (4000 degrees C).

Chromosphere:- The Chromosphere is the next layer of the Sun's atmosphere which is cooler compared to the previous layer. And the temperature of this particular layer is about 7,800 degrees F (4,320 degrees C). Visible light from this layer cannot be seen in ordinary days, they can be seen at the time of solar eclipse only.

Corona:- The innermost layer of the Sun's atmosphere is Corona, in which temperature rises dramatically in this layer. It can get about 3.5 million degrees F (2 million degrees C). This layer cannot be seen in ordinary days except at the time of eclipse.

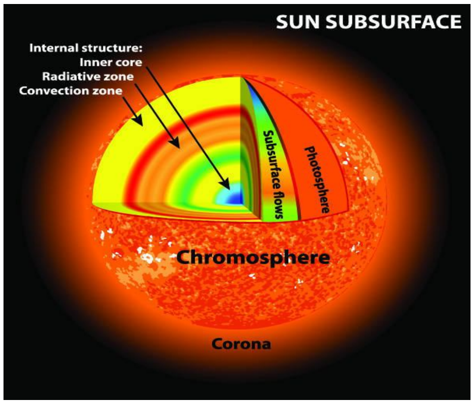

Figure 1:- Layers of the Sun

3. SOLAR ACTIVITY

Solar activity as shown in figure 2, refers to any natural phenomena occurring on or in the Sun, such as: Sunspots, Solar cycle, Solar flares, Solar wind, Coronal mass ejection, Space weather etc. and the collective effect of all of the above on animate and inanimate objects in orbit and on the earth.

Solar variation, the sum of all the periodic and aperiodic solar fluctuations; what is typically referred to when the term "solar activity" is used unqualified.

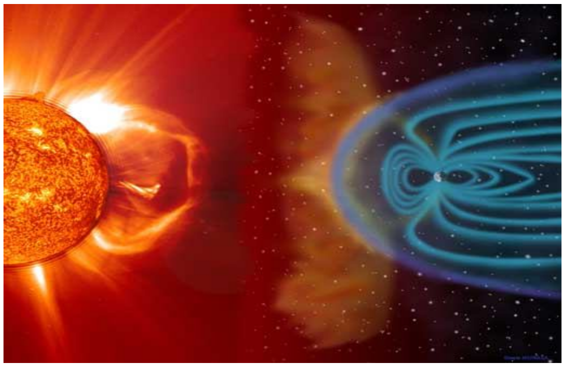

Figure 2:- Solar Activity

In addition to daily fluctuations, activity on the Sun can cause sudden dramatic changes to the ionosphere. The Sun can unexpectedly erupt with a solar flare which is a violent explosion in the atmosphere of the Sun caused due to huge magnetic activity. These solar flares are classified as **A, B, C, X** according to the peak flux , which produce large amount of EUV energy, which travels towards the Earth and other planets with the velocity of light. Its classification is given in figure 3.

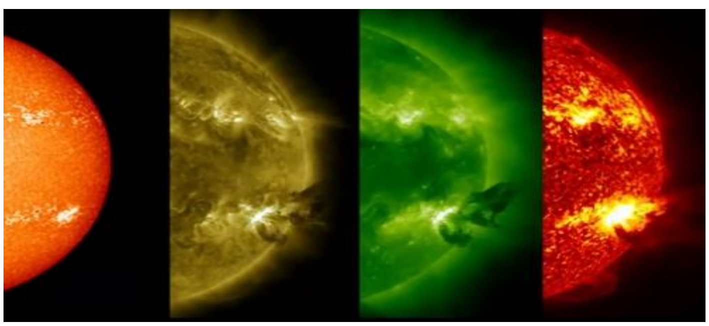

Figure 3:- SOLAR FLARES CLASSIFICATION

4. SOLAR CONSTANT

The Sun is a large sphere of very hot gasses, the heat being generated by various kinds of fusion reactions. Its diameter is about 1.39 X 10^6 km, while that of the Earth is 1.27 X 10^4 km. The mean distance between the Sun and the Earth is 1.50 X 10^8 km. Although the Sun is large, it tends to subtend an angle of 32 minutes at the Earth's surface. The beam radiation received from the Sun on to the Earth is almost parallel. The brightness of the Sun varies from its center to its edge. However for calculations, it is customary to assume that brightness all over the solar disc is uniform.

The rate at which solar energy arrives at the top of the atmosphere is called **solar constant** and is denoted as **I***sc*. *This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the Earth from the Sun*. Because the Sun's distance and activity varies throughout the year, the rate of arrival of solar radiation varies accordingly. The so called solar constant is thus an average from the actual values varies upto about 3% in either direction. This variation is not so important for practical purposes. The **National Aeronautics and Space Administration's (NASA)** standard values of solar constant, expressed in three common units as follows:-

1. 1.353 kw / sq.m or 1353 w / sq.m
2. 116.5 langleys (calories / sq.cm) per hour
3. 429.2 Btu / sq.ft.per hour

The distance between the Sun and the Earth varies a little throughout the year. Because of this variation, the flux also varies.

5. SUN IS AT ONE OF THE FOCI

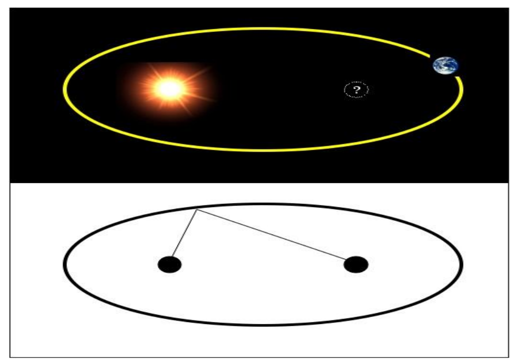

Figure 4:- Position of the Sun at focus

The force of gravity is usually written as $ma = F = -\frac{GMm}{R^2}$. You can rewrite this using vector notation as $m\ddot{\vec{x}} = -\frac{GMm\vec{x}}{|\vec{x}|^3}$, where the dot on top is a time derivative. To keep the notation both standard and confusing, $\vec{x} = (x, y)$.

$$m\ddot{\vec{x}} = -\frac{GMm\vec{x}}{|\vec{x}|^3}$$
$$\Rightarrow \ddot{\vec{x}} = -\frac{GM}{|\vec{x}|^3}\vec{x}$$
$$\Rightarrow \dot{\vec{x}} \cdot \ddot{\vec{x}} = -\frac{GM}{|\vec{x}|^3}\vec{x} \cdot \dot{\vec{x}}$$
$$\Rightarrow \dot{\vec{x}} \cdot \ddot{\vec{x}} = -\frac{GM}{(\vec{x}\cdot\vec{x})^{3/2}}\vec{x} \cdot \dot{\vec{x}} \qquad \{\vec{x}\cdot\vec{x} = |\vec{x}|^2$$
$$\Rightarrow \frac{d}{dt}\left[\frac{1}{2}\dot{\vec{x}} \cdot \dot{\vec{x}}\right] = \frac{d}{dt}\left[\frac{GM}{(\vec{x}\cdot\vec{x})^{1/2}}\right] \qquad \left\{\frac{d}{dt}(\vec{x}\cdot\vec{x}) = 2\vec{x}\cdot\dot{\vec{x}}\right.$$
$$\Rightarrow \frac{d}{dt}\left[|\dot{\vec{x}}|^2\right] = \frac{d}{dt}\left[\frac{2GM}{|\vec{x}|}\right]$$
$$\Rightarrow |\dot{\vec{x}}|^2 = \frac{2GM}{|\vec{x}|} + c$$

c is an "integration constant", it can be any number. Jumping over to polar coordinates $\begin{pmatrix} x = R\cos(\theta) \\ y = R\sin(\theta) \end{pmatrix}$ you can rewrite the usual velocity in terms of how fast you're moving toward or away from the Sun $(\dot{R})$ and how fast you're going around $(\dot{\theta})$.

$$\begin{aligned}
&\Rightarrow \dot{R}^2 + R^2\dot{\theta}^2 = \frac{2GM}{R} + c && \left\{ \begin{array}{l} |\vec{x}| = R \\ |\dot{\vec{x}}|^2 = \dot{R}^2 + R^2\dot{\theta}^2 \end{array} \right. \\
&\Rightarrow \left(\frac{dR}{d\theta}\dot{\theta}\right)^2 + R^2\dot{\theta}^2 = \frac{2GM}{R} + c && \left\{ \frac{dR}{dt} = \frac{dR}{d\theta}\frac{d\theta}{dt} \right. \\
&\Rightarrow \left(\left(\frac{dR}{d\theta}\right)^2 + R^2\right)\dot{\theta}^2 = \frac{2GM}{R} + c \\
&\Rightarrow \left(\left(\frac{dR}{d\theta}\right)^2 + R^2\right)\frac{L^2}{R^4} = \frac{2GM}{R} + c && \left\{ R^2\dot{\theta} = L \right. \\
&\Rightarrow \left(\frac{1}{R^2}\frac{dR}{d\theta}\right)^2 + \frac{1}{R^2} = \frac{2GM}{L^2 R} + \frac{c}{L^2} \\
&\Rightarrow \left(\frac{1}{R^2}\frac{dR}{d\theta}\right)^2 + \frac{1}{R^2} = 2\alpha\frac{1}{R} + C && \left\{ \begin{array}{l} C = \frac{c}{L^2} \\ \alpha = \frac{GM}{L^2} \end{array} \right.
\end{aligned}$$

L is the angular momentum of the planet in question, and it's constant. It may seem silly but, with the advantage of foresight, it's better to solve this problem in terms of 1/R instead of R.

$$\begin{aligned}
&\Rightarrow \left(-\frac{dS}{d\theta}\right)^2 + S^2 = 2\alpha S + C && \left\{ \begin{array}{l} S = \frac{1}{R} \\ \frac{dS}{d\theta} = -\frac{1}{R^2}\frac{dR}{d\theta} \end{array} \right. \\
&\Rightarrow -\frac{dS}{d\theta} = \sqrt{-S^2 + 2\alpha S + C} \\
&\Rightarrow d\theta = \frac{-dS}{\sqrt{-S^2 + 2\alpha S + C}} \\
&\Rightarrow \int d\theta = -\int \frac{dS}{\sqrt{-S^2 + 2\alpha S + C}} \\
&\Rightarrow \theta + D = -\int \frac{dS}{\sqrt{C + \alpha^2 - (S-\alpha)^2}} \\
&= \int \frac{\sqrt{C+\alpha^2}\sin(u)du}{\sqrt{C+\alpha^2 - (C+\alpha^2)\cos^2(u)}} && \left\{ \begin{array}{l} S - \alpha = \sqrt{C+\alpha^2}\cos(u) \\ dS = -\sqrt{C+\alpha^2}\sin(u)du \end{array} \right. \\
&= \int \frac{\sin(u)du}{\sqrt{1-\cos^2(u)}} \\
&= \int \frac{\sin(u)du}{\sqrt{\sin^2(u)}} \\
&= \int du \\
&\Rightarrow \theta + D = u \\
&\Rightarrow \cos(\theta + D) = \cos(u) \\
&\Rightarrow \sqrt{C+\alpha^2}\cos(\theta + D) = \sqrt{C+\alpha^2}\cos(u) \\
&\Rightarrow \sqrt{C+\alpha^2}\cos(\theta + D) = S - \alpha \\
&\Rightarrow \frac{1}{R} = S = \alpha + \sqrt{C+\alpha^2}\cos(\theta + D) \\
&\Rightarrow R = \frac{1}{\alpha + \sqrt{C+\alpha^2}\cos(\theta + D)} \\
&\Rightarrow R = \frac{P}{1 + \epsilon\cos(\theta + D)} && \left\{ \begin{array}{l} P = \frac{1}{\alpha} = \frac{L^2}{GM} \\ \epsilon = \sqrt{\frac{C}{\alpha^2} + 1} \end{array} \right.
\end{aligned}$$

The choice of P and ε may seem arbitrary (and it is), but it has some historical relevance. P is called the "semi-latus recturn" and it basically describes the size of the orbit. ε is called the "eccentricity", and it describes how lopsided the orbit is. ε=0 means the orbit is a circle, 0<ε<1 means the orbit is elliptical, and 1≤ε means that the orbit is open (not actually orbiting). For reference, the Earth's eccentricity is ε=0.01671123 and Halley's comet's is ε=0.967.

D just describes what direction the far side of the ellipse points in, so it's not actually important to the overall shape.

It turns out that this last equation relating R and θ is all you need to define an ellipse, such that the center of the system, (0,0), is at one of the foci. Here's a proof:

An ellipse with a focus at (0,0) can be written $\frac{(x+F)^2}{A^2} + \frac{y^2}{B^2} = 1$ where F is the distance from the center of the ellipse to the focus and $F^2 = A^2 - B^2$.

$$\begin{aligned}
&R = \frac{P}{1 + \epsilon\cos(\theta)} \\
&\Rightarrow R + \epsilon R\cos(\theta) = P \\
&\Rightarrow \sqrt{x^2 + y^2} + \epsilon x = P && \left\{ \begin{array}{l} x = R\cos(\theta) \\ y = R\sin(\theta) \end{array} \right. \\
&\Rightarrow \sqrt{x^2 + y^2} = P - \epsilon x \\
&\Rightarrow x^2 + y^2 = P^2 - 2P\epsilon x + \epsilon^2 x^2 \\
&\Rightarrow (1-\epsilon^2)x^2 + 2P\epsilon x + y^2 = P^2 \\
&\Rightarrow x^2 + 2\frac{P\epsilon}{1-\epsilon^2}x + \frac{y^2}{1-\epsilon^2} = \frac{P^2}{1-\epsilon^2} \\
&\Rightarrow x^2 + 2\frac{P\epsilon}{1-\epsilon^2}x + \left(\frac{P\epsilon}{1-\epsilon^2}\right)^2 + \frac{y^2}{1-\epsilon^2} = \frac{P^2}{1-\epsilon^2} + \left(\frac{P\epsilon}{1-\epsilon^2}\right)^2 \\
&\Rightarrow \left(x + \frac{P\epsilon}{1-\epsilon^2}\right)^2 + \frac{y^2}{1-\epsilon^2} = \frac{P^2(1-\epsilon^2)}{(1-\epsilon^2)^2} + \frac{P^2\epsilon^2}{(1-\epsilon^2)^2} \\
&\Rightarrow \left(x + \frac{P\epsilon}{1-\epsilon^2}\right)^2 + \frac{y^2}{1-\epsilon^2} = \frac{P^2}{(1-\epsilon^2)^2} \\
&\Rightarrow \frac{\left(x + \frac{P\epsilon}{1-\epsilon^2}\right)^2}{\left(\frac{P^2}{(1-\epsilon^2)^2}\right)} + \frac{y^2}{\left(\frac{P^2}{1-\epsilon^2}\right)} = 1
\end{aligned}$$

Put it all together, and you'll find that this is definitely an ellipse with a focus at the point (0,0), the location being orbited around (like the Sun for instance) as shown in figuer 4.

6. Solar Flux

The amount of solar energy reaches the photosphere of the Earth is termed as Solar Flux. By determining the solar flux, ideal propagation can be obtained. Radiation from the sun can be determined at several radio frequencies, out of which 2800MHZ with a wavelength of 10.7 cm is commonly used. The signal which transmits with this frequency is termed as **Solar Flux**. By measuring this one can determine the affect of radiation by the sun on ionosphere. Higher value of solar flux indicates that high frequencies can propagate. As the amount of solar energy emitting from is non uniform, also the amount of energy reaching the earth is non uniform hence there exist seasonal changes, therefore the effect of communication is different in different seasons.

6.1 USE OF SOLAR FLUX FOR EFFICIENT COMMUNICATION

This paper deals, how the efficient communication can be done by utilizing solar flux erupted from the Sun. Whenever the high frequency electromagnetic wave transmitted from the transmitter, hits the ionosphere, reflection to the desired destination depends on the **coefficients of reflection and absorption**. If sun is more active more spots are generated and more radiation is produced which can affect the Earth's ionosphere. Therefore when infernos are high **Ionosphere's reflection coefficient is extremely high and absorption is almost zero** which provides worldwide propagations. The ability of the ionosphere to reflect **high frequency radio signals** depends on amount of solar radiations. Solar activity influences all radio communications beyond ground wave or line of sight. When sun is active frequencies upto 40MHZ or more can be useful for long wave communication all over the globe. Hence by these infernos efficient communications are obtained. The device which is used for ionosphere communication is **H.A.M Radio** shown in figure 5.

Figure 5:- Base station and Handy type HAM Radios

Mathematical Approach

All planets rotate and revolute in a fixed elliptical orbits as shown in figure 7. Some important properties of ellipse are:-

1. There are two points in ellipse called foci.
2. Also sum of the distances to foci to any point on ellipse is constant (a + b = constant)
3. Amount of *'flattering'* is termed as eccentricity.

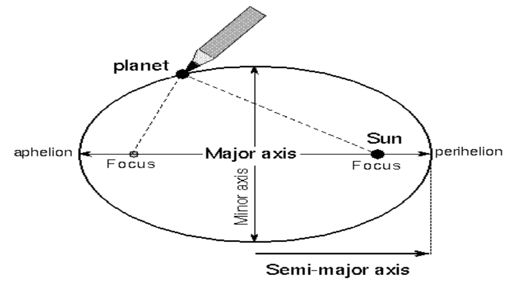

Figure 6:- Ellipse

Solar flux calculation:-

$$\textbf{Solar flux } S\ (w/m^2) = S_0 \times \left(\frac{1A.U}{r}\right)^2 \qquad \text{———— (1)}$$

Where r = distance between Earth and Sun

$S_0 = 1370\ w/m^2$

$1A.U = 1.5 \times 10^{11}$ mts

OR

$$\textbf{Flux} = \frac{\text{luminosity}}{4\Pi R^2}\ w/m^2 \qquad \text{———— (2)}$$

Where – luminosity = 3.8×10^{26} W

Researches proved that the average distance between Sun and Earth is about 150 million km and substituting all the values in the equation (1) we get **Flux = 1343 w/m² (approx)**

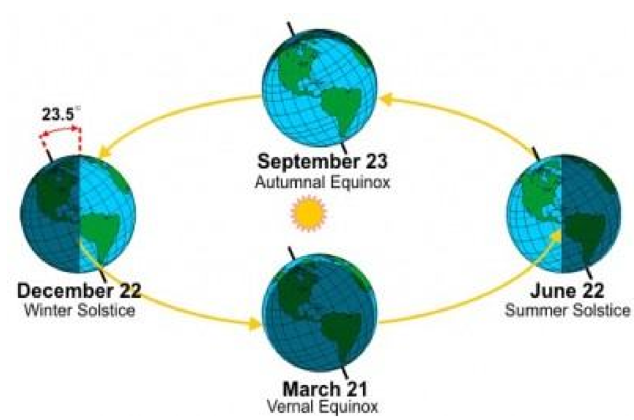

Figure 7:- Position of Earth in different seasons

Points to note

1. From eq (1) it is clear that flux (S) depends on the distance between Sun and Earth (R)

2. Both are inversely related to each other. Therefore as the square of the distance decreases flux increases.

3. So in seasons like summer as the distance is less, the amount of solar flux increases, which in turn activates the ionosphere and makes effective radio propagation.

KEPLER THEME:- The areas of triangles formed between the focus and two opposite points on the ellipse are same.

Now let us assume that Sun is at exact at one of the foci of the ellipse as shown in figure 8. Also assume Sun as an isotropic source ie .radiating equally in all directions, though it not, however for our calculations it is assumed that the brightness of the solar disc is constant.

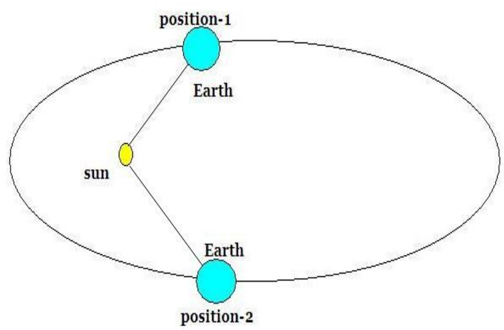

Figure 8:- Two different positions of Earth which are at equal distances from Sun.

On assuming the first position of the Earth as mid September and the second position of the Earth which is exactly opposite to the first as mid March. As the distance from the isotropic Sun is equidistant, therefore the amount of solar flux(S) reaching the Earth is same, which is somewhat related to Kepler theme. Therefore the communication effect results the same in mid September and in mid March. On considering a semi major part of ellipse, the amount of solar flux reaching the earth is same in all opposite points as shownin figure 9.

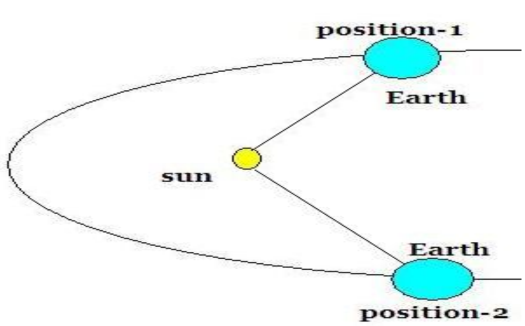

Figure 9:- Semi major part

Many researches declared that a wavelength of 10.7 cm is commonly used.

$$\Delta = \frac{c}{f} \qquad (3)$$

On substituting 10.7 in eq (3) we get f = 2800MHz, over which devices like Ham radios works efficiently.

Pros:-

1. Increase of spots activity increases the solar flux and improves radio propagation.

2. Ionization can be done even at night times by cosmic rays.

3. A class flares and B class flares gives effective ionization without affecting the earth.

4. Devices like HAM are much efficient in ionospheric propagation..

5. Infernos do not last for many hours.

Cons:-

1. Most powerful radiations like X class radiations effects the earth.

2. Temperature may increase more and more.

3. There are also health issues for pilots and astronauts.

4. Lack of ozone layer extensive UV radiations may reach the Earth.

7. CONCLUSION

Communication plays a very important role in our lives, So it would be wise to develop gadgets like HAM Radios which are amiable to nature rather than using high radiation mobiles which harms both people and Mother Nature.

Although, the formation of sunspots , solar flares eruption increases the temperatre on the Earth, the solar flux emmiting from the Sun is advantageous for effective communication.

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