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Theoretical Review of Solar Radio Burst III (SRBT III) Associated With of Solar Flare Phenomena

Z.S.Hamidi[1,2,]*, Ungku Ferwani Salwa Ungku Ibrahim[1,3], Abidin, Z.Z[1], Ibrahim, Z.A.[1], N.N.M.Shariff[1]

[1]Department of Physics, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Faculty of Applied Sciences, MARA University of Technology, UiTM 40450 Shah Alam Selangor, Malaysia
[3] Physics Division, Centre for Foundation Studies In Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

Email: zetysharizat@siswa.um.edu.my

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ABSTRACT

This article broadly reviews our knowledge of theoretical solar radio burst type III (SRBT III) in the low frequency region. The eruption mechanism of solar flares and type III are currently an extremely active area of research especially during the solar cycle is towards maximum. There is a particular focus on their physical properties, as opposed to the microphysics such as that needed for the evolution and formation of this burst or particle acceleration as such. In this work we summarize the related theory, model, significant parameters and relate it with the behavior of the burst in low range frequency. Although this is only a combination of all significant literature, it is hoped that it will give some idea on how to understand in details on this burst.

Keywords: Solar radio burst type III (SRBT III), solar flare, Langmuir waves, Stochastic Growth theory
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INTRODUCTION

One of the most important uncertainties in climate models is the role of Sun activities. It is believed that solar activities such as and solar flares have a very close connection and significant impact of the climate changes and Earth's environment. Therefore it is important to study the phenomena in details. In ground-based observations radio region plays a significant role due to a wide range of coverage with different type of bursts. Solar radio bursts are considered to be a significant characteristic of solar activity because they are generally attributed to a sudden acceleration of particles from the Sun. In the radio frequency range, the Sun has both slowly varying and rapidly varying components (Kundu, 1965; V.V. Zheleznyakov, 1969). An extensive study of solar radio burst type III (SRBT III) associated with solar flare event was carried out actively since 1958 (V. L. Ginzburg & Zheleznyakov, 1958).During the explosion, these active regions relatively have strong magnetic fields with denser and hotter compared with their surroundings and enhanced radio burst typically from 10-100 minutes. There are many mechanisms have been proposed to explain (SRBT III) properties. So far, however, there is still a lack of knowledge about the corona structure and the apparent randomness of the phenomenon. Literature review of this paper concentrates on the development of (SRBT III) and implementation in the low frequency radio region. The present work is aimed to understand the formation of (SRBT III) by looking at several parameters that will evolve this burst. The theoretical (SRBT III) is described in Section 2. Detailed investigation of parameter solar burst type III will be highlighted in Section 3 and the discussion and conclusion are summarized in the last section.

SOLART BURST TYPE III

Solar radio burst type III (SRBT III) is related to solar flare events. Flare is definitely as a relatively rapid brightening in the photon spectrum of the Sun caused by a choking off the normal energy from the corona by the strong closed magnetic field of a plage (Pneuman, 1967). The eruption mechanism of solar flares and type III are currently an extremely active area of research especially during the solar cycle is towards maximum In this case, the total energy of solar burst type III is of the order of 1015 ergs. It occurs in the impulsive phase, which is more intense at meter wavelengths and may have a continuum attached to it (Goldman & Smith, 1986). This burst usually associated with a single flare or flare-like events that excited through the lower solar corona in a bunch of electrons which emit l-waves (electron plasma waves) incoherently (D.B.Melrose, 1970). The electron is thought to be accelerated within a second or so (P. A. a. C. Sturrock, B.A, 1966). In between of the process, the instability is formed and sustained through velocity dispersion, whereby the high energy electron fluxes race ahead of the low energy electron fluxes creating a transient bump-on-tail instability in the reduced, one-dimensional distribution $(\partial f(r)/\partial v) > 0$. In specific range, the event starts with a group of metric type III bursts at 200-400 MHz (Benz, Monstein, & Meyer, 2005). As the beam excites plasma waves at the local plasma frequency, the frequency changes with density can be represented as

$$\omega_p = \sqrt{\frac{4\pi e^2 n_e}{m_e}} = \pi 90 \sqrt{\frac{n_e}{10^8 cm^{-3}}}\ [MHz] \qquad (1)$$

Where e is the element charge, me is the electron mass and ne the electron density. In general there are two (2) classes of generation mechanisms of type III bursts: (i) nonlinear wave-wave coupling processes (Lin, Levedahl, Lotko, Gurnett, & Scarf, 1986) the coalescence of two (2) Langmuir waves, first proposed by (V. L. Ginzburg & Zheleznyakov, 1958), and (ii) the highly nonlinear process proposed by Yoon (P. H. Yoon, 1995; P. H. Yoon, 1997) and direct emission mode conversion due to density inhomogeneity (Field, 1956; D. B. Melrose, 1980; V. V. Zheleznyakov, 1970).

A standard homogeneous quasi-linear theory argues that the back-reaction to wave growth should plateau the beam, remove its free energy, and cease the production of Langmuir-like waves and radiation within much less than 100 km of the source of the beam (P. A. Sturrock, 1964). However, one possible clue is that nonlinear wave processes limit the wave growth by removing wave energy from the linearly unstable region of phase space (Kaplan & Tsytovich, 1973; Papadopoulos, Goldstein, & Smith, 1974). For a monochromatic, plane Langmuir wave with angular frequency, wave vector and electric field, the nonlinear dispersion equation:

$$1 + \frac{\omega_p}{4}\, WG\,(\Omega, K)\left[\frac{cos^2\theta}{\omega(k-K) - \omega(K) + \Omega(K)} + \frac{cos^2\theta}{\omega(k-K) - \omega(k) + \Omega(K)}\right] = 0 \qquad (2)$$

Here $W = \frac{\varepsilon_0 E2}{4 n_e k_B T_e}$ is the dimensionless electrostatic energy density in the pump Langmuir wave (note the factor of 4), n_e is the average electron number density, k_B is Boltzmann's constant, and T_e is the electron temperature. Other participating waves are the low-frequency response at frequency Ω and wave vector κ (often an ion acoustic-like wave) and Langmuir waves with frequencies $\omega(\kappa \pm K)$ and wave vectors $\kappa \pm K$. The angles $\theta\pm$ are those between κ and $\kappa \pm K$, respectively. The quantity $G(\Omega, K)$ is the Green function for the density response at Ω(K) to the pump Langmuir wave at $\omega\ (\kappa)$, with

$$G(\Omega, K) = \frac{dZ_f(z)/dz}{\left(\frac{M_i}{T_i k_B - [dZ_f(z)]/dz}\right)} \qquad (3)$$

where M_i is the ion mass, $Zf(z)$ is the plasma dispersion function for a reduced, one-dimensional velocity distribution $f(v)$ of ions with thermal speed Vi, and $z = \Omega/(2)1/2KVi$ (V. L. Z. Ginzburg, V. V. , 1958). Following (I. H. Cairns, Robinson, & Smith, 1998), $f(v)$ is approximated as a generalized Lorentzian distribution with $\kappa = 2$ and $f(v) \propto (v - 4)$ at high v. Observations show that the solar wind ions typically have significant nonthermal tails, while (Collier, Hamilton, Gloeckler, Boschler, & Sheldon, 1996) data argue specifically for generalized Lorentzian distributions. With this choice for $f(v)$, $Zf(z)$ takes a simple form and equations (2) and (3) can be rearranged to yield a fifth-order polynomial equation in complex $\Omega(K)$ with coefficients depending on K, k, W, and the ratio Te/Ti of the electron and ion temperatures (I. H. Cairns et al., 1998). An important question concerning the origin of type III bursts is how they correlate with the mildly relativistic electrons and Langmuir waves produced from the electrons. It should be noted that observations show that Langmuir waves associated with solar type III radio bursts are highly localized (D. A. Gurnett & Anderson, 1976; D. A Gurnett & Anderson, 1977). One fundamental theory that we believed is that Landau resonance with the unstable electron beam is responsible generates Langmuir waves, which are thought to undergo nonlinear wave-wave interactions that produce electromagnetic emissions at the local electron plasma frequency (fpe) and its second harmonic (2fpe) (Bardwell & Goldman, 1976; Lin et al., 1986; D. B. Melrose, 1982; P. A. Robinson, Cairns, & Willes, 1993a; P. A. Robinson, Willes, & Cairns, 1993b; Smith, Goldstein, & Papadopoulos, 1979).

The second question concerning the origin of type III bursts is how the generated Langmuir waves can convert to electromagnetic waves either the fundamental or the second harmonic of the electron plasma frequency associated with the observed bursts. However, there is an initiative to explain in detail by a stochastic - growth theory which is developed to explain the nonlinear saturation level of Langmuir waves in comparison (P. A. Robinson, 1992; P. A. Robinson, Cairns, & Gurnett, 1993).

This theory addresses the development of fluctuations in the waves and unstable distribution due to their self-consistent interaction in the pre-existing inhomogeneous background plasma (I.H. Cairns & al., 2000; I.H. Cairns & Grubits, 2001; I.H. Cairns & Menietti, 2001; I.H. Cairns & Robinson, 1997, 1999; P.A. Robinson, 1995). It is believed that situation in which the time-integrated growth rate of the waves (the gain) is a stochastic variable because of repeated interactions between a free-energy source, waves, and the background plasma that cause the energy source to attain a state close to time- and volume-averaged marginal stability with stochastic fluctuations about that state that affect the wave gain. Until now, the mechanism of the conversion is still not fully to be understood, but still is an issue which needs to be considered. Before discussing SGT, recently discovered type IIId bursts that are believed to be driven by beams with speeds very close to the speed of light (Poquérusse, 1994). However, we can consider a Langmuir wave spectrum with two (2) components: (i) the ‘‘forward’’ spectrum [beam-generated Langmuir waves] and (ii) the ‘‘backward’’ spectrum of Langmuir waves [backscattered Langmuir waves](Willes, Robinson, & Melrose, 1996).

SOLART BURST TYPE III PARAMETERS AND CHARACTERISTICS

In this section, we will highlight briefly several parameters and physical characteristics of type III burst. Table1 listed the fundamental parameter of this burst.

Table.1 Fundamental parameters of solar burst type II and III

Parameter	**Type III**
Characteristics	Fast frequency drift bursts. Usually in groups, Can occur singular or storms (often with underlying continuum). Can be accompanied by a second harmonic.
Duration	Single burst: 1 - 3 seconds Group: 1 -5 minutes Storm: minutes – hours
Associated phenomena	Active regions, flares
Frequency range	10 kHz – 1 GHz

In solar flare perspective, a theoretical scaling law (Yokoyama & Shibata, 1998) for the flare temperature T as:

$$T = \left(\frac{B^3 L}{2\pi\kappa_0\sqrt{4\pi\rho}}\right)^{\frac{2}{7}} \propto B^{\frac{6}{7}}\ (Reconnection) \qquad (4)$$

Where $T, B,$ and κ_0 are the temperature at the flare loop top, coronal magnetic field strength, coronal density, and heat conduction coefficient, respectively. It should be noted that we need to consider the magnetic reconnection which is a highly conducting that rearranged and magnetic energy is converted to kinetic energy, thermal energy, and particle acceleration. Figure 1 shows a schematic illustration of the reconnection model of a solar flare based on the simulation results (Yokoyama & Shibata, 1997). Thick solid lines show magnetic field. In principle, the magnetic energy is released at slow-mode MHD (magneto-hydrodynamic) shocks emanating from the neutral X-point, which is formed as a result of the magnetic reconnection (Petschek, 1964; S. Tsuneta, 1996; S. Tsuneta, Masuda, Kosugi, & Sato, 1997). The ejected reconnection jet collides with the reconnected loops and forms a fast-mode MHD shock. The released heat at the reconnection site is conducted along the field lines down to the chromosphere. Because of the heat input into the dense chromospheric plasma, the plasma there evaporates and flows back toward the corona. At a certain level, reconnection will become very fast, exceed the Alfvén timescale, when some localization mechanism of the resistivity is included (Ugai, 1986) .

DISCUSSIONS AND CONCLUSION

Overall, we can say that all literature that has been studied have provided a better explanation of the formation of solar flares and type III burst. The quantitative theory still needs to be developed for understanding the properties of type III bursts in the lower solar corona and planetary space (D.B.Melrose, 1986). There is also no detailed theory currently exists that is capable of explaining a type III burst from the deep corona to 1 AU and beyond (Iver.H.Cairns & Robinson, 1998). In order to improve the model of solar burst type III, one should consider are the solar flare models depend on certain properties such as sunspot area, McIntosh classifications, Mount Wilson classifications, and various measures of the magnetic field (Huang, Zhang, Wang, & Li, 2013). Moreover, we also take note that the pattern also depends the solar cycle model. It is important to consider all parameter, mechanisms, previous of theory and model to understand in detail the behavior of the formation of this event. Thus to understand and predict the behavior of the Sun is not an easy way. We need to really understand by not neglected the dynamisms of the Sun itself. In our case, we concentrate the low radio region beginning from 45 MHz till 870 MHz. The low frequency radio emission of solar is informative this range can tell us the behavior of the Sun within 0.1 $R_\odot - 0.3\ R_\odot$.

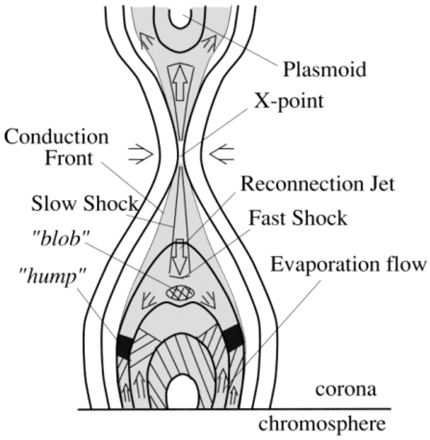

Fig.1 Schematic diagram of the magnetic reconnection of the burst (credited to Yokoyama & Shibata, 1997)

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informative this range can tell us the behavior of the Sun within $0.1R_{\odot} - 0.3\ R_{\odot}$. In other words, they originate in the same layers of the solar atmosphere in which geo–effective disturbances probably originate: the layers where energy is released in Solar Fares, where energetic particles are accelerated, and where coronal mass ejections (CMEs) are launched. Therefore, this region is very important to study. This range is very rich with a single and group of solar burst type III that associated with solar flares. It is meant that it can be considered that there is a large number of solar flares with a tendency to form CMEs. One big challenge of this range is the population of different interference source that might affect the solar burst data. Yet it is still can be eliminated during the analysis process. It is hoped that we could possible to find a latest data that might answered the mechanism of type III burst based on solar flare events.

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