# An Empirical Performance Study of IRNSS S-band Signals under Bluetooth Interference

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## Abstract

Indian Regional Navigation Satellite System operates on L-band and S-band frequencies [1]. The S-band spectrum is congested with several other signals including the signals operating in the license free band. IRNSS S-band signals are therefore more vulnerable to Radio Frequency Interference (RFI) from various terrestrial S-band sources like Wi-Fi and Bluetooth [2]. This paper investigates IRNSS S-band signal performance in the presence of terrestrial Bluetooth signals.

## 1. Introduction

The very promising, Indian Regional Navigation Satellite System (IRNSS) is providing an independent positioning and timing service over Indian land mass and about 1500 Km from the mainland [3]. The system provides accurate real-time position, velocity and time observables for users with a continuous service availability under all weather conditions [4][5][6][7]. The IRNSS constellation consists of a group of seven satellites. Three of the satellites in the constellation (IRNSS 1C, 1F, 1G) are placed in a geostationary orbit and the remaining four (IRNSS 1A, 1B, 1D, 1E) in geosynchronous inclined orbits of 29º inclination relative to the equatorial plane. Such an arrangement is made to ensure all seven satellites would have continuous radio visibility with Indian control stations. A total of 24 MHz bandwidth of spectrum is allocated in the L5-band (1164.45 - 1188.45 MHz) and in the S-band (2483.5 - 2500MHz) for IRNSS. Several investigations have been carried out by researchers on various aspects of IRNSS such as ephemeris errors even before the constellation became fully operational [8], [9]. Several field trials on IRNSS receivers installed at CBIT (17.39° N, 78.31° E), Hyderabad, India have been carried out and published elsewhere [2]. In [2] IRNSS signal robustness has been studied. It is expected that IRNSS S-band signals would be more vulnerable to terrestrial interference from various sources like Wi-Fi, microwaves, Direct Satellite Service (DSS), 2.4GHz phones, wireless speakers, external monitors, baby monitors, and other wireless devices using Bluetooth technology operating in the license free band of 2.4 GHz. Therefore, in this paper it is proposed to study the performance of IRNSS S-band signals in the presence of Bluetooth interference.

## 2. Bluetooth Signal

Bluetooth technology has fundamentally changed the way we work using wireless ergonomic keyboards, hands-free headsets etc. Bluetooth sends signals over 2.4 GHz radio frequency channels, to communicate between devices. This creates interference to other nearby devices using that frequency. Bluetooth technology uses spread-spectrum frequency hopping. That is, there is rotation between 70 randomly chosen frequencies within their range, changing 1,600 times a second. This makes it theoretically unlikely that two devices will share the same frequency for a long time. Bluetooth signals are relatively weak (1 mW), as compared to cell phones (3mW).The Bluetooth received signal power maybe computed using Friis free space equation,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \qquad (1)$$

Where $P_r(d)$ is the received signal power at a distance d (0.5 m) from transmitter, $P_t$ , the transmitted signal power is 1mW assuming a class 3 Bluetooth equipment (Bluetooth radio specification version 1.0A), $G_t$ and $G_r$, the transmitter and receiver antenna gain respectively are both assumed 1 and $\lambda$ is the wavelength of propagating signal (0.125m). $P_r(d)$ is found to be approximately 0.39 μW. Such Bluetooth equipment are used to carry out the experiments.

## 3. S-band Signal Interference Generation

Extensive literature survey suggests that very little work has been carried out on study of IRNSS S-band signal interference performance in the presence of terrestrial Bluetooth signals. Performance of Intra-Vehicular Wireless Sensor Network (IVWSN) under interference from Wi-Fi and Bluetooth devices, occupying the 2.4GHz ISM frequency bands has been evaluated elsewhere [10]. In [10], various experiments have been carried out for different sensor locations inside a car and constant interference has been continuously generated by streaming music from a smart phone to a Bluetooth headset. In this paper, the experimental set-up used is as shown in Fig. 1. Dual frequency IRNSS receivers installed at CBIT, Hyderabad were used for carrying out experiments reported in this work. All the experiments were conducted at an altitude of approximately 20m, thus, ensuring minimal environmental interference. The IRNSS receiver antenna receiving open sky signals from IRNSS satellites was placed in the centre of the experimental setup as is shown in Fig.1. In the near vicinity of the antenna (at 0.5m from it) were placed different component sets to generate and receive Bluetooth signals. Three different component sets or Interference Device Sets (IDS) were used to generate different amount and category of Bluetooth interference. IDS 1 included a Bluetooth (BT) enabled cell phone and a Bluetooth head-set. Music was continuously streamed to the headset from the phone to generate BT interference. Using IDS 2 interference was generated between two Bluetooth enabled phones by continuously transmitting data from one phone to the other. Using IDS 3 interference was generated between two Bluetooth enabled laptop computers by continuously transmitting data from one computer to the other. These are shown in Fig.1 using numbers within brackets beside the nomenclature of the devices.

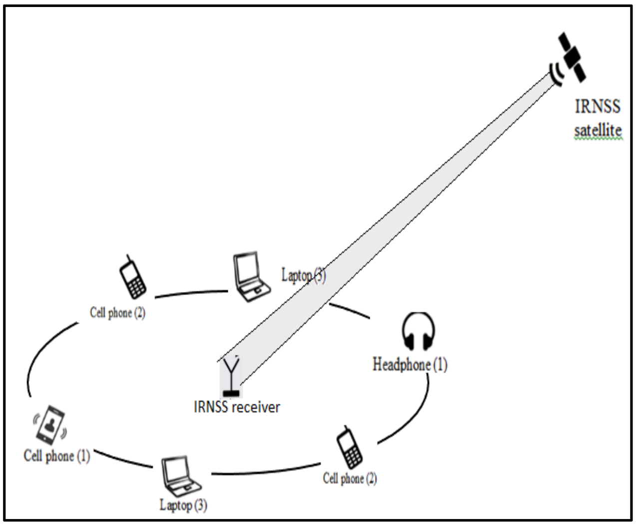


**Figure 1.** Interference created by terrestrial BT signals on IRNSS S-band signals

## 3. Results

The dual frequency C/N measurements for IRNSS 1C on 21 Feb 2017 for around 46 minute (2780 seconds) duration are shown in Fig. 2. In order to generate interference using BT signals it is proposed to introduce the IDS one by one around the vicinity of the IRNSS antenna superimposing the interfering signal strengths one on top of the other. Thus IDS 1 was introduced first. While the IDS 1 was still transmitting, IDS 2 was introduced. While both IDS 1 and 2 were still transmitting IDS 3 was introduced. Finally the IDS signals were withdrawn from the experiment in the reverse order. To be more specific, IDS 1 is introduced at around 1025 seconds. It is observed that the S-band signal drops from 46.97dB-Hz to 43.29dB-Hz immediately. Beyond that the signal fluctuates between 42 and 45 dB-Hz until IDS 2 is introduced at 1524 seconds where the signal drops from 44.51dB-Hz slowly to 41.25dB-Hz. Beyond that time S-band signal fluctuates between 44 and 38.4 dB-Hz. IDS 3 is introduced between 1850 and 2129 seconds. During this period the signal fluctuates between 42 and 35.19dB-Hz. Immediately as IDS 3 is removed, the signal regains strength from 39dB-Hz to 41.29dB-Hz. Beyond that the signal fluctuates between 38.73 and 42.86dB-Hz. At 2345 seconds once IDS 2 is removed the signals jumps to around 44.18dB and fluctuates between 44.38 and 41.76 dB-Hz. Finally at 2494 seconds IDS 1 is also removed. The signal jumps to 45.76 dB Hz and beyond that fluctuates in its normal signal strength variation range. During the entire duration of the experiment it was seen that the L5 signal remained unaffected and was fluctuating between 49 and 54 dB-Hz except at 1088 and 2482 seconds which can be ignored as errors incurred during arrangement of devices etc.

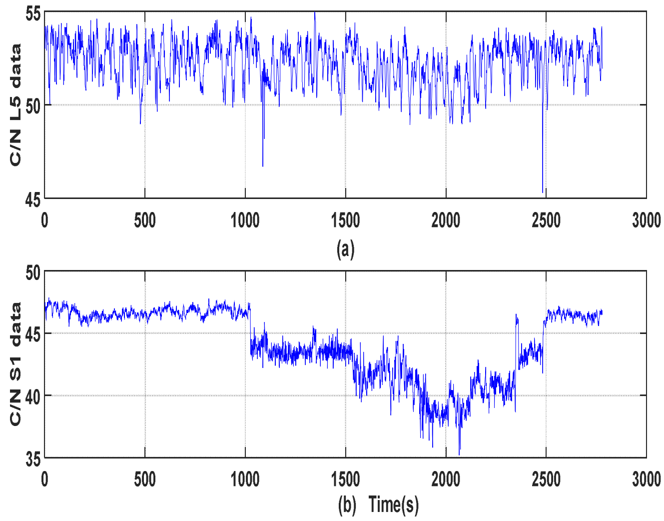


**Figure 2.** C/N measurements for IRNSS 1C on 21st Feb 2017 for a) L5 frequency b) S1 frequency

## 5. Conclusion

It may be concluded that the Bluetooth signals generated by the IDS 1, 2 and 3 interfered with IRNSS S-band signals only and the L-band signals were not much affected. The kind of interference was majorly destructive. It led to loss of IRNSS S-band signal strength every time an IDS was introduced and its Bluetooth signal was superimposed on the previously interfering Bluetooth signal. This phenomenon was ascertained with the fact that the reverse was also true. Every time a component set was removed, the interference was lesser destructive and the S-band signal gained strength. Similar observations were made for other satellites and at different dates. It may be concluded that IRNSS S-band signal faces interference from terrestrial S-band Bluetooth sources. In IRNSS applications, interference is a major degrading factor and could lead to serious errors in position computation. The interference to S1 frequency signals of IRNSS from terrestrial S-band Bluetooth signal sources definitely needs to be mitigated. This will form the future scope of this work. The proposed S-band signal reflector in [2] could also significantly attenuate the S1 frequency signal allowing precise position computation using the L5 band signal of IRNSS.

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