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# Performance Analysis of Flow Meter Using WI-FI Backscatter Technology

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**ABSTRACT:** RF-powered devices are tiny devices which perform communication with the use of electricity which is extracted by RF signals. Now a days technologies uses extracted power which comes through regular radio frequency sources (for e.g. TV), they need a gateway like RFID reader which is only for Internet connection. We have a propensity to provide a Wi-Fi Backscatter, a new communication system which connects RF-powered accessories using the Internet. It has the capability to use the existing Wi-Fi which helps Radio frequency powered devices for internet connection. For showing Wi-Fi Backscatter's working, the design and manufacturing of hardware illustration is done which reveals first combination in radio frequency powered device and a regular Wi-Fi devices. By operating Wi-Fi devices such as Intel Wi-Fi cards, and our organization's Wi-Fi, then supply a communication rate of up to 1 kbps and have a range of up to 3 meters. This novel ability can draw a way for quick implementation and adjust RF-powered devices then have the accordance through mobile devices which are using a Wi-Fi. Our purpose for this work is to design and 3D print of a wireless sensor which will reflect the Wi-Fi signals from commercial Wi-Fi router or mobile hotspot and communicate with the laptop, smartphone or a computer using Wi-Fi receiver or a radio frequency receiver such as Software defined radios (sdr). And this sensors are examined with flow meter to measure flow rate in the pipe for particular application.

**KEYWORDS:** Wi-Fi Backscatter, Internate Of Things, Radio Frequency Identification, Transceiver, Flow Meter, Software Defined Radios, 3D-printing

## I. INTRODUCTION

In current situation most regularly used wireless technology is WI-FI and it is key choice of Internet of things (IOT) applications. Such as Google Home or a famous smart home control product which need Wi-Fi to upload media directly from or to the cloud, to combine these ambient sensors or controllers as the NEST thermometers, smoke alarms, and cams. But the utilization of energy for Wi-Fi has long been a burden. A regular Wi-Fi transceiver takes 80 mW power to send 75 bytes data per second, which is 40 times larger than the Bluetooth. More energy in Wi-Fi and most other remaining wireless technologies are suffer through transmission of signals. Newly, backscatter communication has been changing the area.

Turned out to many studies on backscatter communications, in particular, Radio Frequency Identification (RFID), which is acquirable in the market at a very less prize. Alternately reflecting specific RFID signals, updated knowledge have recommend that a RFID tag can reflect a wide spectrum of signals, like cellular, wireless TV, Wi-Fi, etc. lots of IOT applications are essential of internet and Wi-Fi compatible but it's not mandatory that they need the full set of Wi-Fi functions, Wi-Fi backscatter has received great interest. To work with any WI-FI devices it has dramatically increase the performance of backscatter system. Rather than it also needed a plugged-in device to get the excitation signal.

Backscatter device can enroot tag data on ambient spatial streams, which can be decoded using commercial MIMO Wi-Fi devices.

## II. DESIGN CALCULATIONS

### 1. Flow meter design.

Maximum pressure of the fluid flowing in the industrial pipes is 6000 Pascal. So according to maximum pressure in the pipe the design of flow meter is done. Polybutadiene is the Material used for flowmeter and other components which is common material for 3D printing and properties used for it are used from properties table of Polybutadiene given below.

Property	Minimum Value (S.I.)	Maximum Value (S.I.)	Units (S.I.)	Minimum Value (Imp.)	Maximum Value (Imp.)
Atomic Volume (average)	0.0055	0.0065	m <sup>3</sup> /kmol	335.63	396.654
Density	0.91	0.94	Mg/m <sup>3</sup>	56.8095	58.6823
Energy Content	125	145	MJ/kg	13542.3	15709.1
Bulk Modulus	1.5	2	GPa	0.217556	0.290075
Compressive Strength	2.2	2.5	MPa	0.319083	0.362594
Ductility	5	5.5		5	5.5
Elastic Limit	2	2.2	MPa	0.290075	0.319083
Endurance Limit	0.85	0.935	MPa	0.123282	0.13561
Fracture Toughness	0.07	0.1	MPa.m <sup>1/2</sup>	0.0637033	0.0910047
Hardness		0	MPa		0
Loss Coefficient	0.88	2.1		0.88	2.1
Modulus of Rupture	2	2.2	MPa	0.290075	0.319083
Poisson's Ratio	0.499	0.4995		0.499	0.4995
Shear Modulus	0.0003	0.0007	GPa	4.35113e-005	0.000101526
Tensile Strength	5	10	MPa	0.725189	1.45038
Young's Modulus	0.001	0.0022	GPa	0.000145038	0.000319083

Table 1: Properties of Polybutadiene plastic [12].

P = maximum pressure = 6000 pascals.

b = width of blades = 8mm.

l = length of blades = 15mm.

F = maximum force on a blade.

t = thickness of blade.

z = number of blades.

m = module = 5.

S = maximum bending stress of Polybutadiene = 2.2Mpa = 2.2\*10<sup>6</sup>

Y = Lewis form factor.

P = Force/Area

$$= F/l*b$$

F = P\*l\*b

$$= 6000*0.008*0.015$$

$$= 0.72 \text{ Newton.}$$

Maximum force on blade = 0.72 N.

F = m\*b\*S\*Y

Y = F/m\*b\*S

$$= 0.72 / (5*8*2.2)$$

$$= 0.008$$

Lewis form factor = 0.008 which gives number of blades used in flow meter. i.e.

z = 6

Y = t<sup>2</sup> / (6\*h\*m)

t<sup>2</sup> = Y\*6\*h\*m

$$= 0.008*6*15*5$$

$$= 4$$

t = 2mm



Thickness of blade is 2mm.

2. Gear design.

Maximum force on a gear tooth is considered as 3 Newton.

F = maximum force on gear tooth = 3 N.

m = module of gear 3.33.

z = number of teeth on gear.

d = pitch circle diameter of gear = 40mm.

b = width of gear tooth = 2mm.

h = height of gear tooth = 2mm.

t = thickness of gear tooth.

S = permissible bending stress of Polybutadiene =  $2.2 \times 10^6$  Pa.

Y = Lewis form factor.

$$F = m \cdot b \cdot S \cdot Y$$

$$Y = F / (m \cdot b \cdot S)$$

$$= 3 / (3.33 \cdot 2 \cdot 2.2)$$

$$= 0.202$$

Lewis form factor is 0.202 which shows that number of gear teeth needs to be 12. i.e.

$$z = 12$$

$$Y = t^2 / (6 \cdot h \cdot m)$$

$$t^2 = Y \cdot 6 \cdot h \cdot m$$

$$= 0.202 \cdot 6 \cdot 3.33 \cdot 2$$

$$= 8$$

$$t = 2.8$$

Thickness of gear needs to be 2.8mm.

3. Design of spiral spring.

Moment on spiral spring is considered as 235 N-m.

M = moment on spring = 235 N-mm.

E = modulus of elasticity of Polybutadiene = 0.2 Mpa.

b = width of spring = 2 mm.

l = length of spring = 250mm.

t = thickness of spring.

r = radius of spring coil.

$\theta$  = angle of twist of coil = 300 = 0.5235 rad.

$$\theta = 12 \cdot M \cdot l / (E \cdot b \cdot t^3)$$

$$t^3 = 12 \cdot M \cdot l / (E \cdot b \cdot \theta)$$

$$= 12 * 235 * 10^{-6} * 250 / (0.2 * 2 * 0.5235)$$

$$= 3.367$$

$$t = 1.5$$

Thickness of spring is 1.5mm.

#### 4. Base Design.

Base is designed to support rotating Gear and a spring. So the force on beam is considered as 6 Newton for safety and rigidity from the Gear design.

F = maximum force on beam = 6 newton.

S = maximum permissible stress on beam = 2.2 Mpa.

d = diameter of beam.

$S = F / \text{Cross section area of beam.}$

$$= F / (\pi/4) * d^2$$

$$d^2 = F / (\pi/4) * S$$

$$= 6 / (\pi / 4) * 2.2$$

$$= 3.472$$

$$d = 1.9 \text{ mm}$$

All the designs were printed using Polybutadiene plastic using 3D printer and the antennas were printed using copper for reflecting Wi-Fi waves.

### III. CAD DRAWINGS

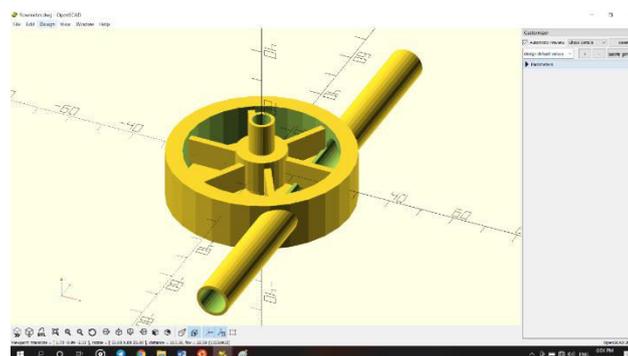


Fig 5.2.1: Flow meter.



Fig 5.2.2: Coded Gears.



Fig 5.2.3: Spring.

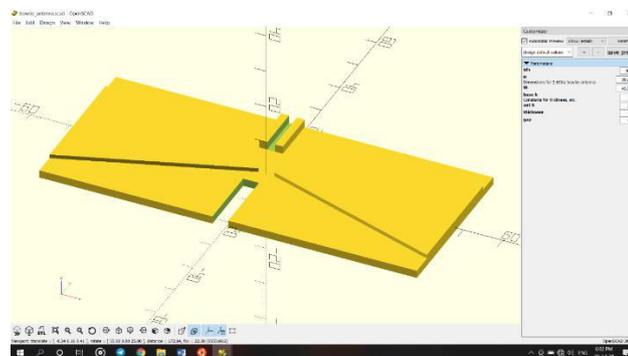


Fig 5.2.4: Backscattering antenna.

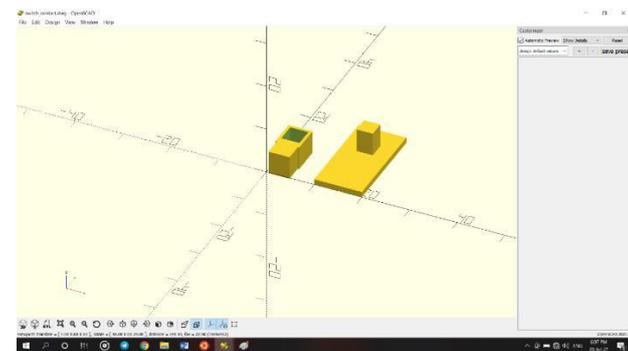


Fig 5.2.5: Switch contact.

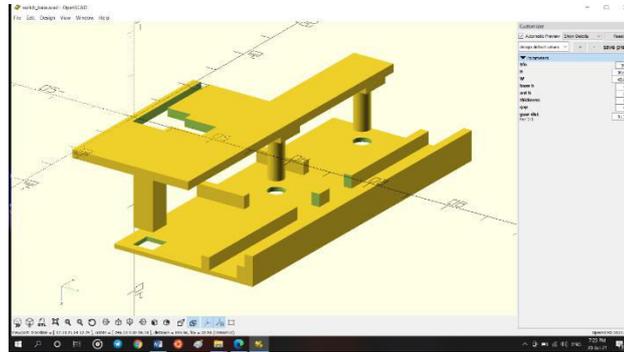


Fig 5.2.6: Base.

### 3. 3D printed components.



Fig 5.3.1: Printed Spring.



Fig 5.3.2: Printed Coded Gear.

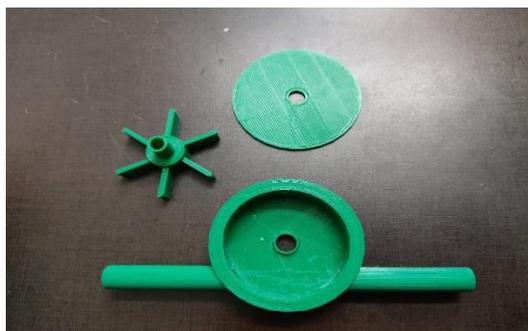


Fig 5.3.3: Printed Flow meter.

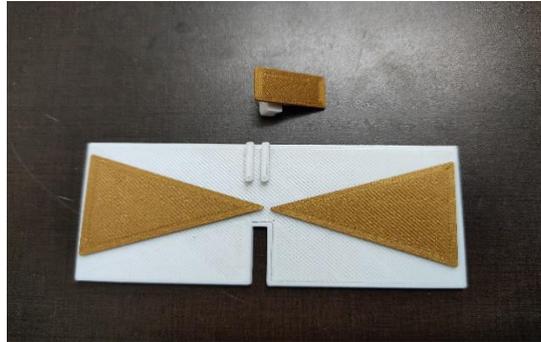


Fig 5.3.4: Printed Backscattering antenna.

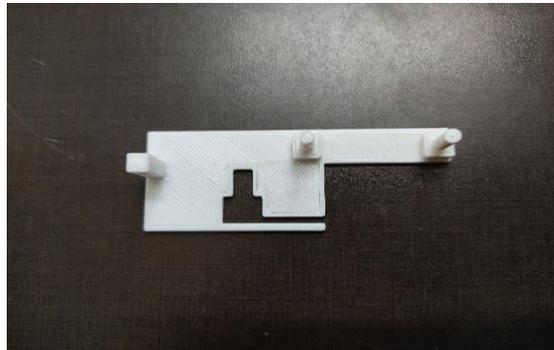


Fig 5.3.5: Printed Base.

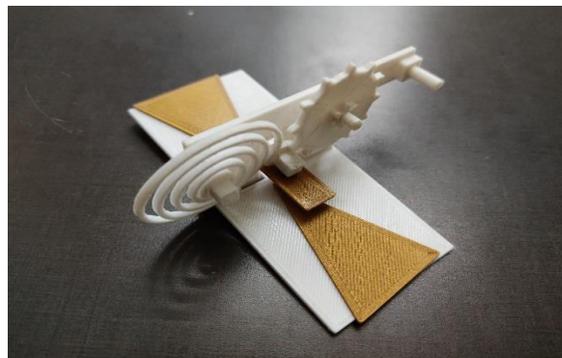


Fig 5.3.6: Full assembly of backscattering switch.

## V. CALCULATION AND MEASUREMENT

### 5.1. Calculation:

Using dimensions of flow meter, Theoretical flow of a flow meter can be calculated. They are calculated as below.

- V = total volume of gap between blades.
- V<sub>c</sub> = volume of casing.
- V<sub>r</sub> = volume of rotor.
- D = inner diameter of casing = 45mm.
- H = height of casing cylinder = 15mm.
- d = diameter of rotor = 15mm.
- h = height of rotor = 10mm
- l = length of blade = 15mm.
- b = width of blade = 8mm.



t = thickness of blade = 2mm.  
 Qt = theoretical volumetric flow rate of water in a pipe.  
 f = frequency of reflected signals.  
 Na = actual speed of revolution measured using optical tachometer.  
 N = speed of revolution in rps.  
 Qa = actual flow rate.  
 Qm = flow rate measured by flow meter.

$$V_c = (\pi / 4) * D^2 * H$$

$$= (\pi / 4) * 452 * 15$$

$$= 23856.5 \text{ mm}^3$$

$$V_r = (\pi / 4) * d^2 * h + l * b * t$$

$$= (\pi / 4) * 152 * 10 + 15 * 8 * 2$$

$$= 2007.1 \text{ mm}^3$$

$$V = V_c - V_r$$

$$= 23856.5 - 2007.1$$

$$= 21849.4 \text{ mm}^3$$

This volume is volume / revolution of rotor.

Using frequency of reflected signals from antenna, Flow rate is calculated. So the frequency will be in cycles / second and 12 cycles = one revolution as gear which actuates the switch has 12 teeth.

Therefore the speed of revolution  $N = (1 / 12) * f$

Volumetric flow rate  $Q_t = V * N_a$

Measurement formula for  $Q_m = V * N$

**5.2. Measurements:**

Following table gives the measured values of frequency, speed of revolution, actual speed of revolution measured using tachometer, theoretical flow rate, actual flow rate and measured flow rate respectively.

Table 2: Measurements

Sr no	f (Hz)	N (rps)	N <sub>a</sub> (rps)	Q <sub>t</sub> (mm <sup>3</sup> /s)	Q <sub>a</sub> (mm <sup>3</sup> /s)	Q <sub>m</sub> (mm <sup>3</sup> /s)
1	278	23.1	23.2	507605	507805	506799
2	269	22.4	22.5	491633	492631	491522
3	297	24.8	24.8	543766	543964	542151
4	283	23.6	23.7	517896	518191	516271
5	279	23.2	23.3	509178	510172	509069
6	294	24.5	24.5	537189	538185	535803
7	276	23.0	23.0	503519	503817	502639
8	281	23.4	23.4	513067	513267	511945
9	262	21.9	22.0	480970	483871	478624
10	290	24.2	24.2	530000	530089	529548

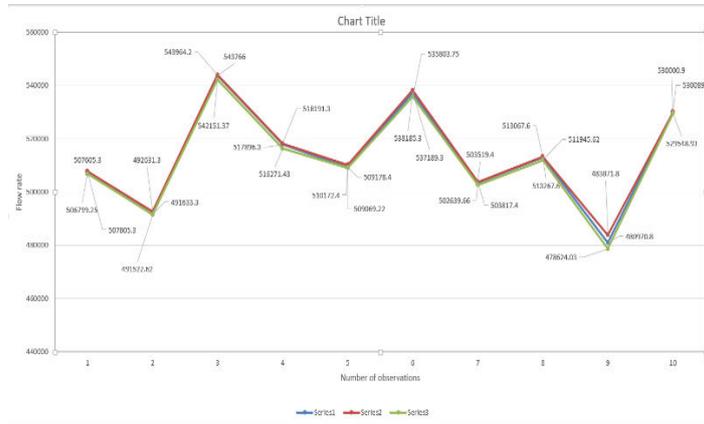


Fig 3: Graph of measured, theoretical and actual flow rate.

### VI. RESULTS AND SNAPSHOTS

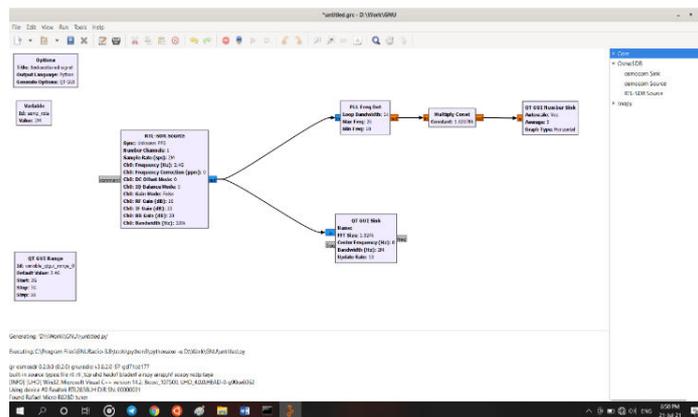


Fig 4: Block Diagram.

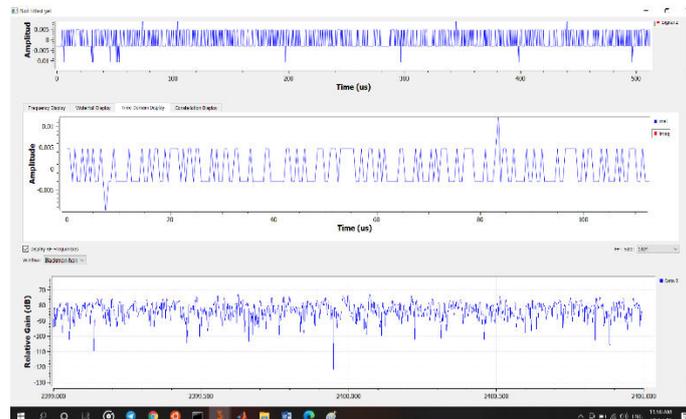
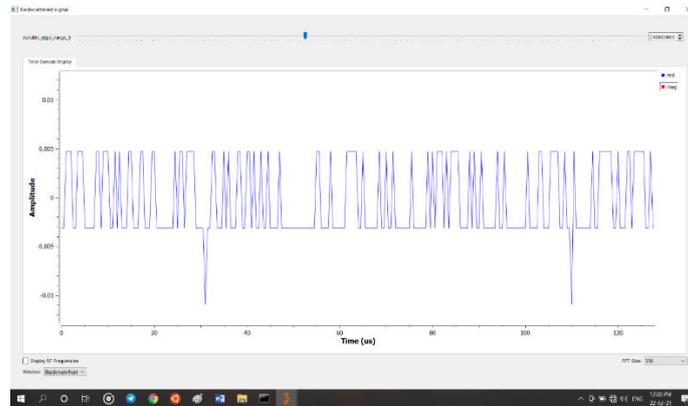
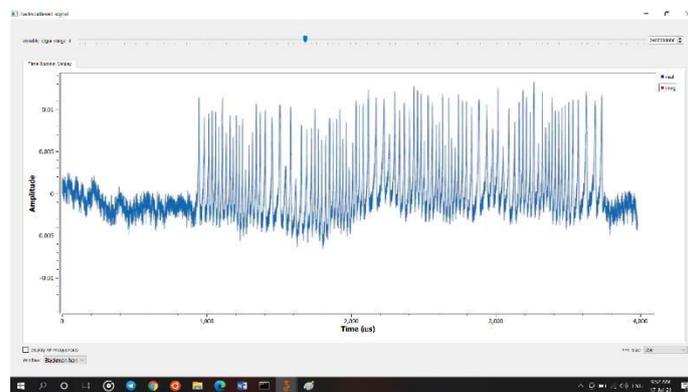


Fig 5: Plot of Frequency vs Gain and Time vs Amplitude.



**Fig 6:** Plot of actual Wi-Fi signal on time vs amplitude.



**Fig 7:** Plot of backscattered signal on time vs amplitude.

The results of signals captured by SDR in GNU Radio Companion software is given by figures above. Fig 4 constitute a block diagram used to capture Wi-Fi signals as well as backscattered signals. Fig 5 display plot of Frequency vs Gain and Time vs Amplitude diagram. Fig 6 display actual plot of Wi-Fi signal on time vs amplitude diagram. Fig 7 display plot of backscattered Wi-Fi signal on time vs amplitude diagram. From the backscattered data the frequency is detected using frequency detect block and the calculations given in measurement are used in the block to find out measured flow rate of fluid in pipe.

## VII. CONCLUSIONS

We conclude that Wi-Fi backscattering technology can be used for developing sensors and IoT devices in the future. These 3D printed sensors have wide range of applications in sensing, tracking, monitoring and robotics. They work in radius of 10 – 14 meter without any interference and loss of signal. These devices have good accuracy within small range of operation such as a sensors. Also we conclude that this technology needs no battery and will have future scope in IoT as most of the current IoT devices uses batteries.

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