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Design And Implementation Of Low Cost Microwave Motion Sensor Based Security System

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Abstract

This paper evaluates the development of a low-cost security system using the microwave technology. The technology chosen is to accurately detect motion of persons in a protected area in outdoor environment. Once detected, an alert is generated to warn persons that the space has been violated. The concepts discussed in this paper serve to detecting way of something to use microwave sensor module which contains k band transceiver, antenna, and Doppler radar theory. The system is designed and developed using simple locally available components and by considering every tiny factor it is made both reliable and affordable. As part of this development, we are performing MATLAB simulation, tolerance analysis, nodal analysis, power analysis and range analysis tools/ techniques.

KEYWORDS: *Microwave Motion sensor, signal conditioning, Doppler Effect, CRO, Active load*

1. Introduction

The primary objective of the systems discussed here is to alert persons when they cross the virtual line-of-fire boundary. In this project, we are using microwave technology because they are more stable and less prone to false alarms. Here, motion sensor plays an important role. Microwave sensors generate an electromagnetic (RF) field between transmitter and receiver, creating an invisible volumetric detection zone. The microwave sensor transmits microwave signals and evaluates returned signals for a moving object. By using this microwave technology, the detector is less sensitive to false alarms. Microwave motion sensors utilize Doppler principle and radar technology, to detect motion of an object.

To reduce the unit cost, the homodyne transceiver front-end was configured into a single waveguide module and a micro-strip planar type patch array antenna was chosen for miniaturization purposes as well.

2. Proposed Scheme

The microwave Doppler module detects the deviance of frequency (so-called Doppler frequency) between transmitting wave from module and returned wave which is attacked to the target, when human or object is moving, and outputs its signal as DC offset voltage. Radars determine v by measuring the frequency shift Δf, via a frequency down-converter in a homodyne transceiver configuration followed typically by a signal conditioning circuitry which amplifies, filters and processes the signal as shown in a Fig.1.

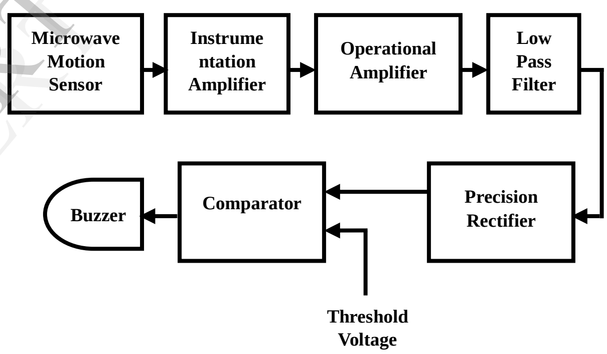


Fig.1 Block Diagram of Proposed Scheme

2.1 Microwave Motion Sensor

Microwave motion sensors are valuable tools in the industrial environment for measuring motion, velocity, direction of movement, and range. They are rugged devices capable of operating in hostile environments, and are intrinsically safe, since they have no moving parts and require low power. They will not cause any harm to operators and will function effectively in explosive environments.

Microwave technology has been an effective method of measuring the parameters of motion and presence. Microwave sensing technology can be classified into 5 categories. They are motion sensing, presence sensing, velocity sensing, direction of motion sensing, range sensing.Microwave sensors utilize electromagnetic fields and devices internally operating at frequencies starting from ~300 MHz up to the terahertz range. Such devices can be found in the following classes: Pulsed radar type, Doppler-effect radars, FM-CW (frequency-modulated, continuous-wave) radars, UWB (ultra-wideband) systems Transmitter-receiver systems, Passive detectors (radiometers) Resonator sensors, Impedance meters, Noise-using devices, Modulated targets. The majority of the above sensor types (except radiometers) utilize a signal generator (transmitter), and a detector (receiver). The differences between them consist in the type of signal modulation and system design. Some microwave sensors can operate at a distance from an object of interest, while other types can be mechanically joined with it.

2.1.1 Characteristics of Microwave Sensors

No contact: Microwave sensors are operate without actual contacting the object and can effectively penetrate nonmetallic surfaces.
Intrinsically safe: They do not generate sparks due to friction or electrostatic discharge
Rugged: They have no moving parts and have proven their reliability in extensive military use.
Long range: They are capable of detecting objects at distance of 25 to 45000mm or greater, depending on the target size, microwave availability and antenna design.
Environmental reliability: Microwave sensors operate from -55°c to +125°c in dusty, dirty, gusty, polluted and poisonous area.
Size of microwave sensors: Advances in microwave circuit development allow the overall package to be significantly smaller and less costly.
Principles of operation: microwave sensor consists of three major parts

1. Transmission source
2. Focusing antenna
3. Signal processing receiver

Usually transmission and receiver are combined together in one module, which is called transceiver.

Microwave sensors require narrow beam high gain antenna, when the beam of microwave energy strikes an object, some of this energy is reflected back to the module as shown in Fig.2. The amount of energy depends on composition and shape of object.

When the reflected energy returns to the transceiver, the mixer diode will combine it with of the transmitted signal as shown in Fig.3. If the target is moving away or towards from module, the phase relationships of these two signals will change and signal out of the mixer will be audio frequency proportional to speed of target, this is called Doppler frequency.

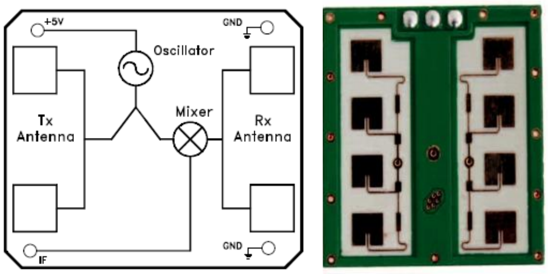


Fig.2 Doppler Module Block Diagram and Connections

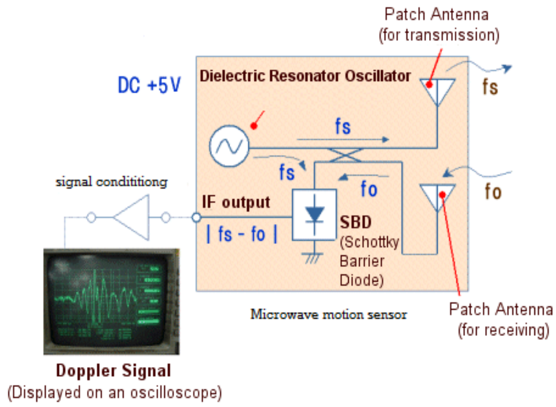


Fig.3 Representation of Sensor Working

The signal from mixer will be in microvolt to millivolt range so that amplification will be needed to provide a useful level. Besides amplification, filtering, comparator and output circuitry relays are also needed to suit the application.

2.1.2 Principle of Operation

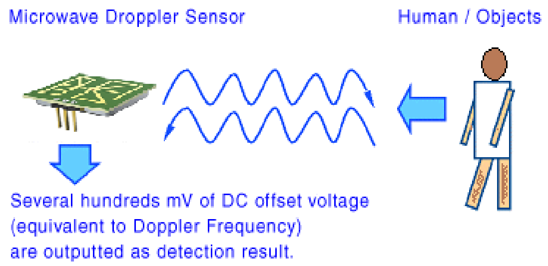


Fig.4 Principle of Operation

- Microwave Motion Sensor Module is developed applying Doppler radar principle as shown in Fig.4.
- The role of Sensor Module is transmitting a low power Microwave from transmitting antenna and receiving the microwave energy reflected by objects to receiving antenna
- If the movement of the object is detected by the microwave motion sensor, the reflected microwave frequency is shifted away from the transmit frequency to receiving antenna
- The reflected and shifted microwave frequency is mixed with the transmit microwave frequency and

results a low frequency voltage at the output of the sensor

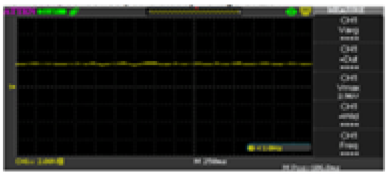
2.1.3 Detection Factors

Six factors typically affect the Probability of Detection (Pd) of most area surveillance (volumetric) sensors, although to varying degrees. These are the: 1) amount and pattern of emitted energy; 2) size of the object; 3) distance to the object; 4) speed of the object; 5) direction of movement and 6) reflection/absorption characteristics of the energy waves by the intruder and the environment (e.g. open area, shrubbery, or wooded).

Theoretically, the more definitive the energy pattern, the better. Likewise, the larger the intruder/moving object the higher the probability of detection. Similarly, the shorter the distance from the sensor to the intruder/object, and the faster the movement of the intruder/object, the higher the probability of detection. A lateral movement that is fast typically has a higher probability of detection than a slow straight-on movement.

When this setup output is connected to digital oscilloscope and following are the results.

i. When no motion sensor output is steady voltage

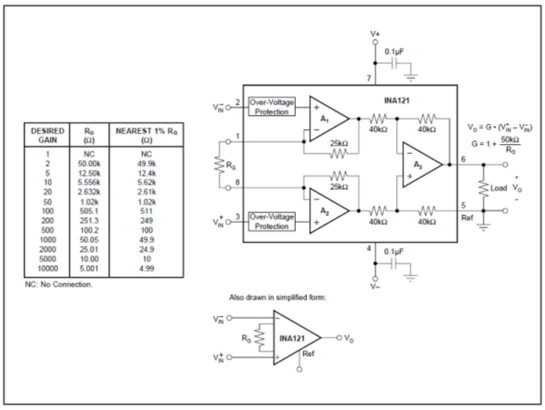


ii. When wave hand in front once and we can see output changing during that time

2.2 Instrumentation Amplifier

FET-input, low power instrumentation amplifier offering excellent accuracy. Its versatile three-op amp design and very small size make it ideal for a variety of general purpose applications. Low bias current (±4pA) allows use with high impedance sources. Gain can be set from 1V to 10,000V/V with a single external resistor. Internal input protection can withstand up to ±40V without damage [4].

Gain of the INA121 is set by connecting a single external resistor, RG, connected between pins 1 and 8. Commonly used gains and resistor values are shown in Fig.5.



DESIRED GAIN	R_G (Ω)	NEAREST 1% R_G (Ω)
1	NC	NC
2	50.00k	49.9k
5	12.50k	12.4k
10	5.556k	5.62k
20	2.632k	2.61k
50	1.02k	1.02k
100	505.1	511
200	251.3	249
500	100.2	100
1000	50.05	49.9
2000	25.01	24.9
5000	10.00	10
10000	5.001	4.99

Fig.5 Instrumentation amplifier

2.2.1 Features

Low Bias Current: ±4pA
Low Quiescent Current: ±450mA
Low Input Offset Voltage: ±200mV
Low Input Offset Drift: ±2mV/°C
Low Input Noise: $20nV/\sqrt{HZ}$ at f = 1 kHz
High CMRR: 106dB
Wide Supply Range: ±2.25V to ±18V
Low Nonlinearity Error: 0.001% max
Input Protection to ±40V

2.3 Operational Amplifiers

The OPA244 series is easy to use and free from phase inversion and overload problems found in some other op amps. These amplifiers are stable in unity gain and excellent performance is maintained as they swing to their specified limits. They can be operated from single (+2.2V to +36V) or dual supplies (Δ1.1V to Δ18V). The input common-mode voltage range includes ground ideal for many single supply applications op-amps are designed for very low quiescent current (50ΔA/channel), yet achieve excellent bandwidth. Ideal for battery powered and portable instrumentation [5].

2.4 Low-Power Differential Comparators

They take advantage of stable, high-value, ion-implanted resistors to perform the same function, with a 30:1 reduction in power consumption, but only a 6:1 slowdown in response time. They are well suited for battery-powered applications and all other applications where fast response times are not needed. They operate over a wide range of supply voltages, from ±18 V down to a single 3-V supply with less than 300-µAcurrent drain, but are still capable of driving a 25-mA load as shown in Fig.6.

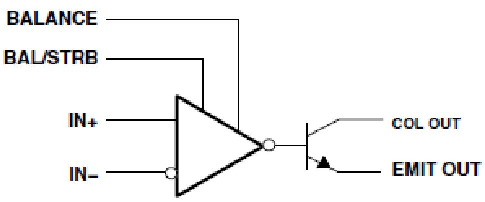


Fig.6 Functional Block Diagram

3. Simulation Model of proposed scheme

Simulation is an important part of any design process. By simulating circuits, we can detect errors early in the process, and avoid costly and time consuming prototype rework. We can also swap components to evaluate designs with varying bills of materials (BOM).

The proposed scheme is completely modeled using MATLAB simulink blocks. It consists of sensor, instrumentation amplifier, operational amplifier, first order low-pass filter, differential comparator as shown in the following Fig.7 and corresponding simulation result as shown in Fig.8.

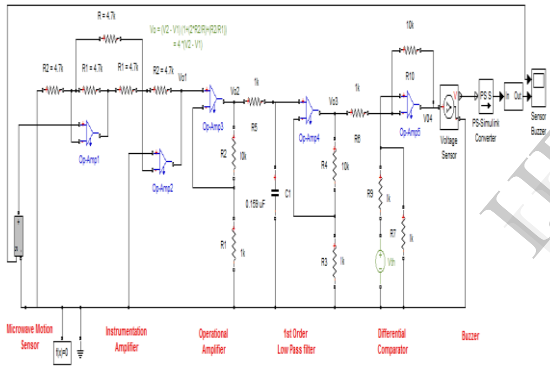


Fig.7 Simulation Model of Proposed Scheme

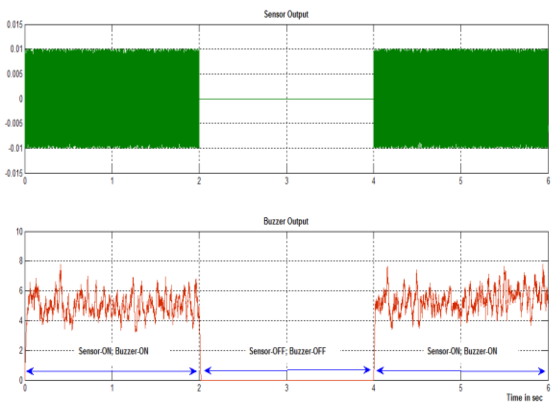


Fig.8 Simulation results

4. Hardware Set-Up

To make the complete design as compact as possible the circuit has been designed using two small boards which are plugged together as shown in above Fig.9.

Fig.9 Complete Circuit Mounted on PCB

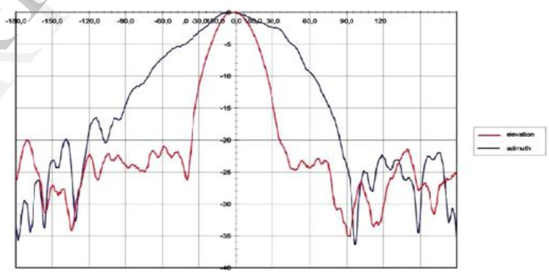


Fig.10 Coverage Pattern

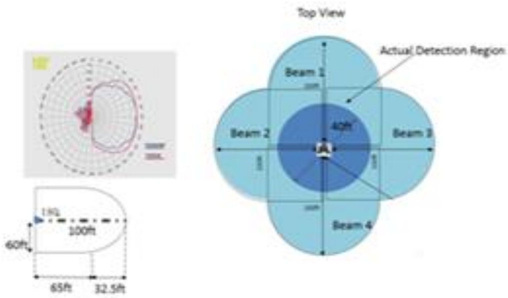
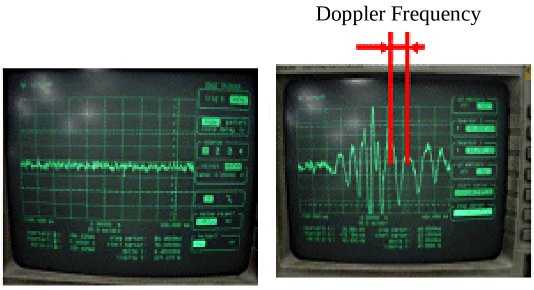


Fig.11 Actual virtual boundary can be controlled via Logic circuit

Antenna beam pattern of the microwave motion sensor and if four numbers of these modules are placed then it covers circular area that is actual detection range is sown in Fig.11. When this setup output is connected to digital oscilloscope, if no object is moving and object is moving then results are followed as shown in Fig.12.



(a) **(b)**

(a) when no object is moving
(b) when object is moving

Fig.12 Hardware result

Table-1: Range in Outdoor Environment

Potentiometer value in Ω	**Amplifier gain in db**	**Range in meters**	**Range in feet's**
25	2000	33	108
30	1667	21.4	70
35	1429	20.5	67
45	1112	14	45
55	910	12.8	41
70	715	9.9	32.4
85	589	8.6	28.2
91	550	8	26

Table-1 shows that the amplifier gain is varied by changing potentiometer value then set the required range of sensor as according to our requirement.

5. Conclusion

A compact, low-cost K-band Doppler sensor module suitable for low end microwave wave applications in outdoor environment also. Its range is varied by varying gain of amplifier are using. The development of this makes the sensor a good fit for the high-volume, low-cost production. It is easy way to overcome the current fundamental problems in detecting and save many precious lives. Motion detection plays a key role in a comprehensive control and protection system for automation.

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