Radar Guns and Relativity

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Abstract: *Radar guns provide an excellent means of explaining and demonstrating some of Einstein's Relativity theories in a fairly simple and undeniable way. Specifically, radar guns demonstrate how the speed of the emitter cannot add to the speed of the light being emitted, but the speed of the receiver/observer affects the energy of the light that is returned to the gun. In practice, this directly conflicts with basic tenets of mathematicians who somehow believe that all motion is relative, and the properties of light will therefore always be the same for the emitter as for the receiver. A step by step analysis of how radar guns work shatters those beliefs.*

Key words: Radar; Relativity; Doppler Effect; speed of light; photon; wave; Einstein.

I. How Radar Guns Utilize Photons.

When describing how radar speed guns work, it is common practice to describe radar guns as emitting **waves** of electromagnetic energy, because waves are easier to visualize, even though such waves do not exist and could not possibly work. In reality, radar guns emit **photons**. A quote from Physicist Richard Feynman describes the problem:

> "I want to emphasize that light comes in this form — particles. It is very important to know that light behaves like particles, especially for those of you who have gone to school, where you were probably told something about light behaving like waves. I'm telling you the way it does behave — like particles."[1]

The "particles" are called "photons." The word "particle" simply means that it is a unit or quantum of energy, not some wave-form of energy spreading out through some substance like air, water or the imaginary "ether" that was once assumed to fill the universe.

Professor Feynman then went on to explain that you can use a photomultiplier to count photons coming from some source. If you dim the source light, the number of photons hitting the photomultiplier is reduced, but the intensity or energy of each individual photon remains the same. And, of course, when you intensify the source light, the number of photons increases. Therefore, light and all transmitted electromagnetic energy consists of photons, not waves.

Photons are electromagnetic energy being transferred from one atom to another. The energy is in the form of oscillations of the photon's electric and magnetic fields. A person can visually see an oncoming vehicle because sunlight in the form of photons is hitting atoms in the vehicle, and those atoms then re-emit new photons in all directions. The person can see the vehicle because those new photons hitting his eyes oscillate in the visible light range.

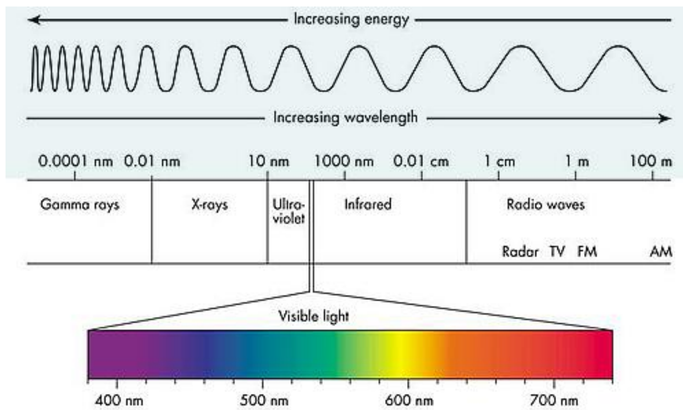

Figure 1

Figure 1 above shows how "wavelengths" identify the type of photon. Visible light photons have wavelengths in the range of about 350 *nanometers* to 750 *nanometers*. The word "radar" is an abbreviation of **RA**dio **D**etection **A**nd **R**anging. Police Radars use wavelengths in the radio range. A radar gun that emits photons which oscillate at 35 Gigahertz (35,000,000,000 times per second) means the wavelength is about 8.5655 *millimeters*, close to 1 centimeter in Figure 1. A radar gun that emits photons which oscillate at 24.125 Gigahertz means the wavelength is about 1.24 *centimeters*.

The frequencies used by radar guns are chosen because nothing else uses frequencies in that range. AM radio stations generally use 525 to 1705 kilohertz (kHz), frequencies which translate to wavelengths of 571 *meters* to 175 *meters*. FM uses 88 to 108 megahertz (MHz) which translates to wavelengths of 3.4 *meters* to 2.8 *meters*. WiFi uses frequencies ranging from 2.4 GHz to 6 GHz, which translates to wavelengths of 12.5 *centimeters* to 5 *centimeters*.

The electric and magnetic field oscillations of a photon traveling at the speed of light have properties that can be viewed as being similar to waves, but which are also very *different* from waves, because between every two "crests" (i.e., full expansions) of a photon's magnetic field there is a "crest" (i.e., full expansion) of its electric field.

Figure 2 below shows how the fully expanded magnetic field of a photon contracts as the electric field expands at a 90 degree angle to the magnetic field.

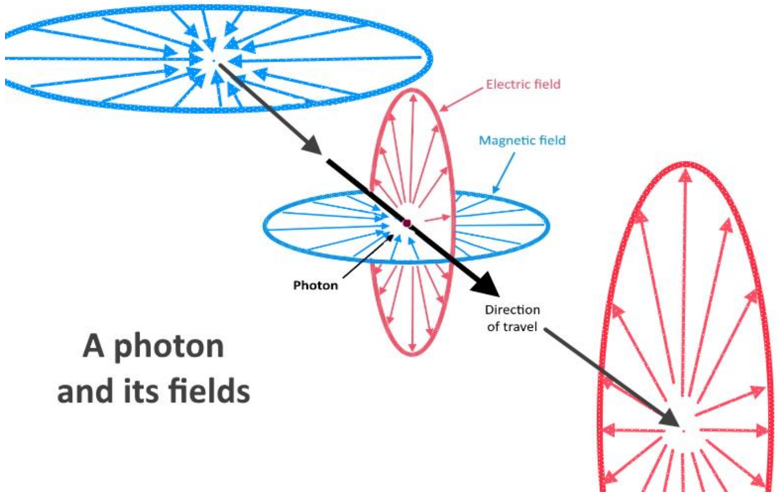

Figure 2

Figure 3 below shows how each fully expanded magnetic field is separated by a fully expanded electric field, which means that "the crest to crest wavelength" is actually twice the length that would be measured for waves.

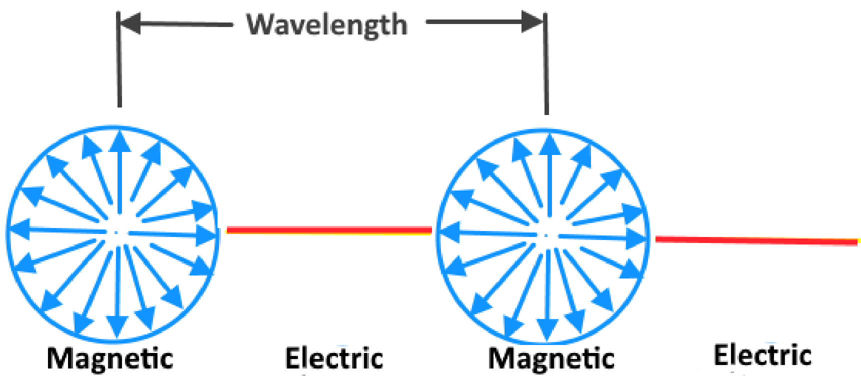

Figure 3

Additionally, since there are two kinds of "waves" being intermingled, the *frequency* of the "waves" depends upon what you are measuring. If you are measuring "waves," you will get twice the number per second that you will get if you are just measuring electric "waves." This will become important later when the Hertz frequency per second of the electric "waves" has to be multiplied by 2 in order to get the correct frequency to convert the photon oscillation frequency to miles per hour (see Figure 8 on page 7).

A NASA web site[2] describes how a stationary police radar gun can, in theory, use a single photon to measure the speed of an oncoming car. The radar gun is pointed at the oncoming car and the gun emits a photon. "The force exerted by the car on the photon, … acts to add energy to the photon. Therefore, we expect the photon frequency to increase." And, "The police radar detector easily detects this frequency shift."

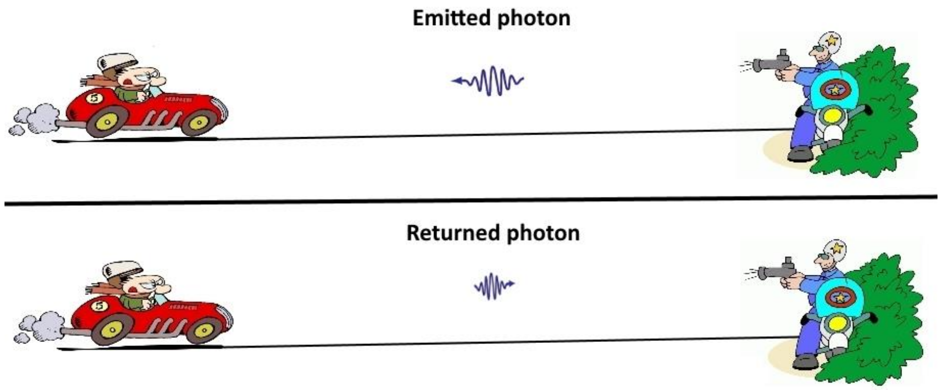

Figure 4

This means that, as illustrated in Figure 4 above, a radar gun can theoretically emit one perfectly aimed photon at the front bumper of the target vehicle. The photon, of course, travels at the speed of light, which is 186,282 miles per second, also known as *c* in mathematics. Because the target is moving, time ticks at a slightly slower rate for the target in accordance with Time Dilation and Einstein's Theory of Special Relativity. That simply means the photon hits the target at *c*, which is still 186,282 miles per second, but the length of a second as measured at the target is slightly longer. Nevertheless, when a radar gun using the 35 Gigahertz (GHz) frequency emits a photon that oscillates at that frequency, the frequency of the photon that is returned to the gun from the target will vary depending upon the speed of the target. The change in frequencies is the result of what is called "The Compton Effect."[3][4]

The Compton Effect occurs when kinetic energy from the moving target is added to the original energy of the received photon. An electron inside an atom within the moving target absorbs the incoming photon as if the photon had higher energy and a higher oscillating frequency than was originally emitted. The kinetic energy that is added directly relates to the motion of the target. The electron cannot retain the extra energy of the photon, so the electron emits a *new* photon to get rid of that extra energy. Most of the new photons are scattered in random directions, but if the atom is in a highly reflective surface, such as chrome, the new photon will be emitted directly back toward the radar gun. That new photon has a shorter wavelength (and a higher oscillating frequency and higher energy) than the original photon. When that photon is returned to the stationary radar gun, the gun can compute the speed of the moving headlight by measuring the difference between the oscillation frequency of the photon the gun emitted and the oscillation frequency of the photon that came back.

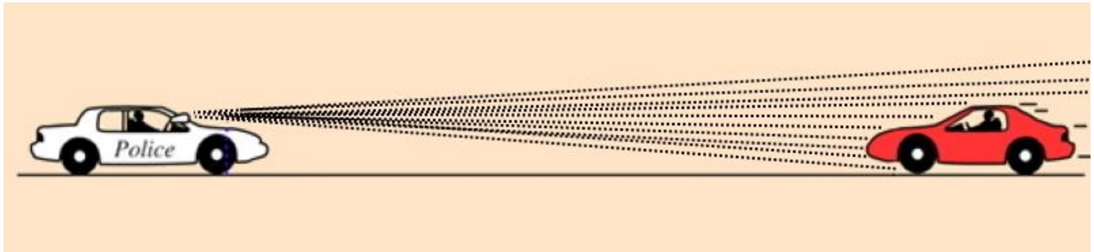

Figure 5

In reality, of course, the radar gun emits a stream of trillions of photons for as long as the trigger is being pulled, as shown in Figure 5 above. A typical radar gun has a narrow funnel-shaped transmitter that is about 2 inches in diameter at the end facing the target. The 2-inch cone of photons will spread to about 75 feet in diameter by the time it hits a moving target if the target is about 500 feet away. Only a tiny fraction of those photons will actually hit a smooth reflective surface on the target vehicle, like its bumper or one of its headlights. The additional returned photons from the target ***verify*** what could theoretically have been measured by a **single** photon. Most of the photons will hit other parts of the car plus the ground, trees, parked cars, telephone poles and other stationary objects. The atoms in most of those objects will emit and scatter **new** photons in many directions, and only a very tiny fraction of those new photons will actually get back to the 2-inch receiver on the radar gun.

Of course, the receiver must ignore all the photons from other sources, such as reflected light, Wi-Fi, radio and TV transmissions, and gamma rays from distant stars. Just as a radio can tune to a given frequency, a radar gun is finely "tuned" to the specific frequency used only by that *specific* type of radar gun.

II. Radar gun frequencies and the "beat frequency".

In the United States, the most common frequency range (particularly for hand-held police radar guns) is 33.4 to 36.0 Gigahertz (GHz), known as the "Ka band." "K band" radar guns which use 24.125 GHz and 24.150 GHz are also common.

As previously mentioned, when those "waves" hit an oncoming moving object, there will be a "Compton Effect," meaning that the "waves" will be compressed and will "echo" back at a higher frequency than at which they were originally transmitted. The difference between the transmitted frequency and the returning frequency is called the "beat frequency."

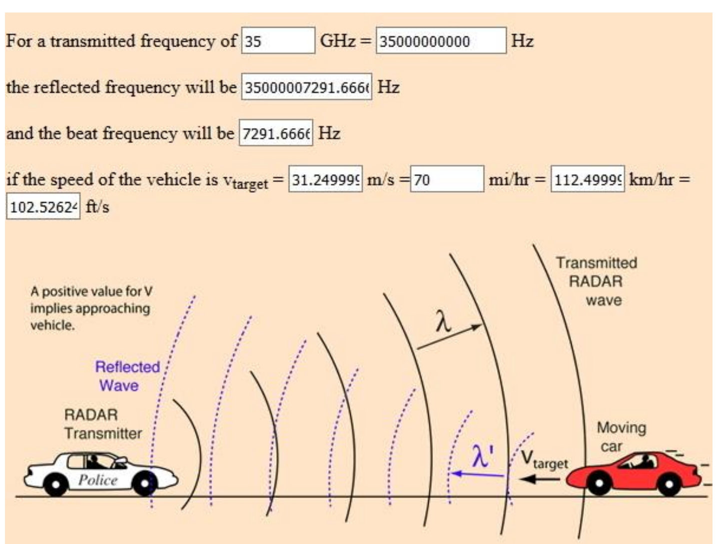

Figure 6

Figure 6 above is an illustrated example from an on-line calculator[5] for the beat frequency. It shows that if a stationary radar gun transmits 35,000,000,000 "waves" per second, and if the oncoming target vehicle is traveling at 70 mph, the returning "waves" will be received at 35,000,007,292 per second (when rounded off to the nearest Hz). The gun "beats" together the emitted and received "waves" to get a "beat frequency" of 7,292 Hz, which is the oscillation frequency difference between what the gun emitted and what it received back.

That poses a question: How do you get from knowing the beat frequency is 7,292 Hz to determining at what speed the target is traveling? The table in Figure 7 below shows how the beat frequency for a given speed is always the same <u>percentage</u> of the emission frequency, regardless of what emission frequency you are using. At the bottom, the table shows the percentage that a given speed is of the speed of light (SOL).

Hertz	Speed	Beat Frequency	Beat % of Hertz
24125000000	100	7180.0595245361	0.0000297619047%
24150000000	100	7187.5	0.0000297619047%
33400000000	100	9940.4761886597	0.0000297619047%
35000000000	100	10416.6666641235	0.0000297619047%
36000000000	100	10714.2857131958	0.0000297619047%
24125000000	70	5026.0416679382	0.0000208333333%
24150000000	70	5031.25	0.0000208333333%
33400000000	70	6958.3333320618	0.0000208333333%
35000000000	70	7291.6666641235	0.0000208333333%
36000000000	70	7500	0.0000208333333%
24125000000	40	2872.0238113403	0.0000119%
24150000000	40	2875	0.0000119%
33400000000	40	3976.1904754639	0.0000119%
35000000000	40	4166.6666641235	0.0000119%
36000000000	40	4285.7142868042	0.0000119%
		100 mph % of SOL	0.0000149116932%
		70 mph % of SOL	0.0000104381545%
		40 mph % of SOL	0.0000059646597%

Figure 7

Figure 7 also shows a key fact about radar guns: <u>You do not need to know your exact transmission frequency</u>. Whatever frequency you are using, the beat frequency for 70 mph will always be the same percentage of the transmission frequency. That is essential, since a radar gun's internal parts will "warm up" as you hold the trigger, and it will then emit photons that oscillate at a slightly higher frequency. In cold weather the gun will emit photons that oscillate at a lower frequency. Fortunately, the gun will not change temperature in any significant way between emission and the receiving of the returning photons a tiny fraction of a second later.

Another key fact is that a transmitted photon travels to the target at the speed of light, 670,616,629 miles per hour, or 186,282 miles per second. And during each of those seconds, the photon's electric and magnetic fields oscillate a specific number of times. That means the beat frequency as a percentage of the transmission frequency is translatable into miles per hour as a percentage of the speed of light.

All this is due to the "Compton Effect" discovered by Arthur H. Compton and described in a paper he wrote in 1923,[6] for which he won the Nobel Prize. It also means that, technically, radar guns do not measure the "Doppler Effect" since they actually measure a difference in the **energy** between two photons. That energy difference corresponds to a difference in oscillation frequencies, which can be viewed as a difference in "wavelength," but the "waves" are nothing like sound waves or water waves.

If the emission frequency is 35 GHz, and the target is moving at 70 mph, the beat frequency is 7,292 Hz, which is 0.0000208333333% of the transmitted frequency. The percentage that 70 mph is of the speed of light is 0.0000104381545%, which is almost exactly ½ of the beat frequency percentage. Knowing that fact, the radar gun software can be programmed to multiply the transmission frequency by 2 before using the resulting adjusted beat frequency to compute the speed of the target.

Figure 8 below shows how knowing the electric "wave" transmission frequency, knowing that there is a magnetic wave between every two electric "waves," knowing the speed of light, and using that information to develop the beat frequency, enables a radar gun to compute the speed of a target.

Hertz	Hertz x 2	Beat Frequency	Beat % of (Hertz x 2)	← as % of SOL	Rounded
24125000000	4825000000	7180.0595245361	0.00001488095238%	99.7941412139%	100
24150000000	4830000000	7187.5	0.00001488095238%	99.7941412139%	100
33400000000	6680000000	9940.4761886597	0.00001488095238%	99.7941412139%	100
35000000000	7000000000	10416.6666641235	0.00001488095238%	99.7941412139%	100
36000000000	7200000000	10714.2857131958	0.00001488095238%	99.7941412139%	100
24125000000	4825000000	5026.0416679382	0.00001041666666%	69.8558988095%	70
24150000000	4830000000	5031.25	0.00001041666666%	69.8558988095%	70
33400000000	6680000000	6958.3333320618	0.00001041666666%	69.8558988095%	70
35000000000	7000000000	7291.6666641235	0.00001041666666%	69.8558988095%	70
36000000000	7200000000	7500	0.00001041666666%	69.8558988095%	70
24125000000	4825000000	2872.0238113403	0.00000595238%	39.9176501013%	40
24150000000	4830000000	2875	0.00000595238%	39.9176501013%	40
33400000000	6680000000	3976.1904754639	0.00000595238%	39.9176501013%	40
35000000000	7000000000	4166.6666641235	0.00000595238%	39.9176501013%	40
36000000000	7200000000	4285.7142868042	0.00000595238%	39.9176501013%	40

Figure 8

As stated before, the Hertz frequency used by the gun is used to obtain the "beat frequency" by simply subtracting the Hertz frequency from the frequency returned by the target. Then the gun's programming computes what percentage that beat frequency is of 2 times the Hertz frequency. When that percentage is computed, the same percentage is used against the speed of light. The result is the speed of the target (when rounded to the nearest whole number) as shown in the table in Figure 8.

When I discussed this with a radar engineer, he informed me that my description was basically correct, but radar gun engineers have developed the math one step further. They use the speed of light to calculate a "K-factor," which is the beat frequency representing 1 mile per hour for a given transmission frequency. Then you just need to get the beat frequency, divide it by the K-Factor and you get the target speed in miles per hour, as shown in Figure 9 below.

GHz	Beat Freq.	K-factor	Speed
24.15	7187.5	72.023	99.7945100871
24.15	5031.25	72.023	69.8561570609
24.15	2875	72.023	39.9178040348

Figure 9

III. The Cosine Effect.

Everything described above assumes the target is approaching or receding directly toward or away from the radar gun. If the target is moving at some angle to the radar gun, the gun will read a lower speed than the actual speed of the target. This is called "the cosine effect" because the measured speed is directly related to the cosine of the angle between the radar and vehicle direction of travel or speed vector. The greater the angle the greater the speed error and the lower the measured speed.

If the angle to the target is 20 degrees, and the target is actually moving at 70 mph, the radar gun will read 65.8 mph. A 30 degree angle produces a speed of 60.6 mph. 40 degrees produces a speed of 53.6 mph. 50 degrees produces a speed of 45 mph. 70 degrees produces a speed of 23.9 mph. And an angle of 90 degrees results is a measured speed of zero.

What this also means is that Einstein's Velocity Time Dilation is not relevant to the operation of radar guns. A target moving at 70 mph across the surface of the Earth experiences a slowing of time regardless of its direction of movement relative to the radar gun. What changes when the angle to the radar gun changes is the amount of <u>**energy**</u> that is transferred from the target to the photon hitting the target. When a photon hits a target at a 50 degree angle, less energy is transferred to the photon than if the photon hits at a 40 degree angle. So, to simplify matters, the rest of this paper only describes how radar guns operate when the target is at a 0 degree angle, coming head-on or moving directly away from the radar gun.

IV. The Two Types of Radar Guns

Hand held radar guns can be organized into two general categories: "**stationary only"** radar guns and "**moving mode"** radar guns.

Figure 10 below shows a "stationary only "radar gun being pointed at an oncoming vehicle that is traveling toward the gun at 55 miles per hour. Figure 11 shows a "moving mode" radar gun in the same situation. As the name implies, a "stationary only" gun can only be operated *officially* while stationary, and it displays only one speed, which is presumed to be the speed of the target. The "moving mode" gun, however, can be used while stationary (as shown) or while moving. It has digital display that will display not only the speed of the target when the gun is stationary (as shown) but when moving can *also* show the speed of the radar gun (i.e., the speed of the patrol vehicle in which the gun is being carried, known as the "patrol speed").

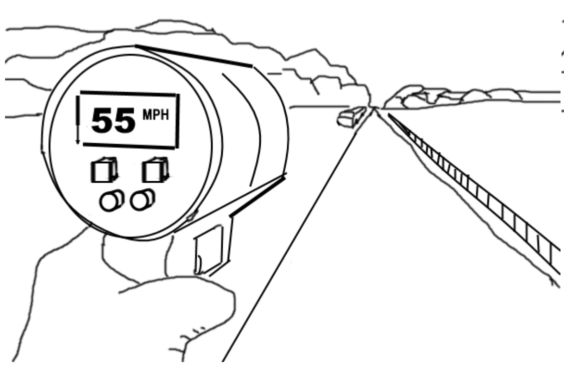

Figure 10

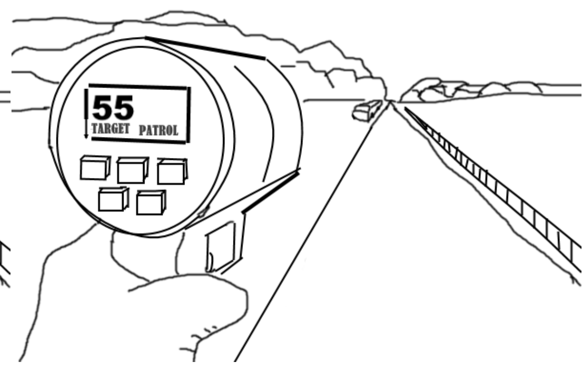

Figure 11

One point of confusion is that a gun that **looks like** Figure 11 can also be a "stationary only" gun. Radar gun manufacturers will strip out internal parts to make "stationary only" versions for customers who have no need for the more expensive "moving mode" guns. When that is done, the gun in Figure 11 may work just like the gun in Figure 10, and the "patrol speed" side of the display may be used for other information, such as displaying the "fastest speed" when there are multiple targets.

V. Traffic Radar Patent U.S. #3,118,139[7]

The first patent for a "Speed Measuring Apparatus" that can measure the speed of a moving target when the "apparatus" is also moving was U.S. #3,118,139. It was issued to Gerald Durstewitz of Pompton Lakes, New Jersey, on January 14, 1964. The description begins with this:

> *This invention relates to apparatus for measuring the speed of a body relative to a surface over which it is moving, and more particularly, to such apparatus which is mounted on a second body adapted to move over the Surface and operates on the Doppler principle to measure the speed of the first body with respect to the surface while the second body is moving.*

Durstewitz's patent is referenced in nearly every subsequent patent involving radar guns that can be used while moving.

Figure 12 below is an illustration from the patent showing how the apparatus works when the patrol car is following behind the target.

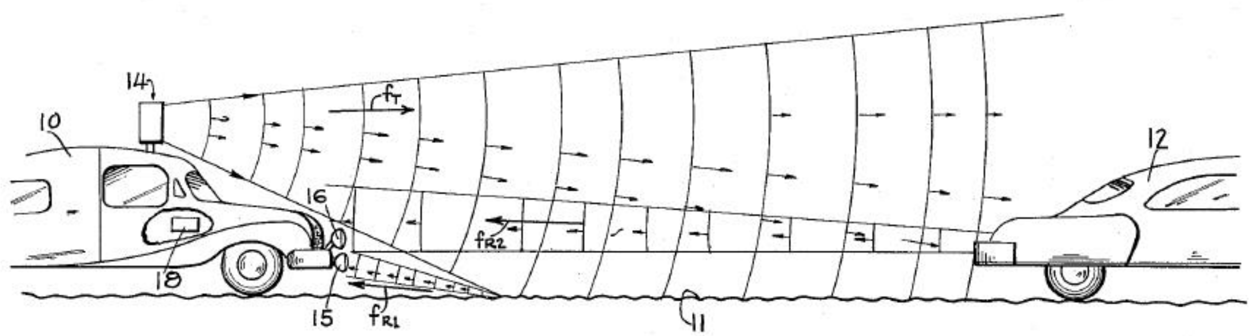

Figure 12

The transmitter is item #14, the large box atop the patrol car which is item #10 on the left. It transmits photons with frequency FT. The apparatus has **two** receivers, items #15 and #16, affixed to the front bumper of the patrol car. Receiver #16 receives photons (with frequency FR2) that come from the rear of the target car (item #12), and receiver #15 receives photons (with frequency FR1) that come from the ground just ahead of the patrol car. (Interestingly, radar gun patents *never* use the word "photon." Durstewitz avoids the wave-particle debate by using a neutral term, "radiations.") The Durstewitz patent says,

> *Those radiations received by the transducer 15 have a frequency FR1 which differs from the transmitted frequency FT by an amount proportioned to the speed of the automobile 10 relative to the surface 11. Those radiations received by the transducer 16 have a frequency FR2 which differs from the transmitted frequency FT by an amount proportional to the speed of the automobile 10 relative to the automobile 12.*
>
> *It has been discovered that the difference between the frequencies FR1 and FR2 is proportional to the speed of the automobile 12 relative to the surface 11.*

That discovery is correct. In plain English, the first paragraph says that photons received by receiver #15 have a frequency (FR1) that differs from the transmitted frequency (FT) by an amount proportional to the speed of the patrol car (60 mph). Correct. The photons received by receiver #16 have a frequency (FR2) that is proportional to the *difference* in speeds between the two cars, i.e., 10 mph. That is also correct. The next paragraph in the description says it has been discovered that the difference between the two frequencies (60 vs 10) is proportional to the speed of the target relative to the ground, i.e. 50 mph. That is also correct.

It would also be correct if the target was coming toward the patrol car. The numbers would then be 110 vs 60, which again produces 50 mph as the difference.

But how can that be done when you have a hand-held **gun** that has only **one** receiver? Answer: With a radar gun that performs two measurements, (1) the ground speed and (2) the combined ground and target speeds, the gun's computations just need to use programmable logic to verify that the strongest return signal does indeed represent the ground speed and not the target speed. Then it is a simple matter to subtract the ground speed from the combined speed to get the target speed.

VI. Traffic Radar Patent U.S. #3,936,824[8]

On February 3, 1976, a patent for a "Method and Apparatus for Digitally Measuring Speed" was issued to John L. Aker and others working for Kustom Electronics, Ltd., of Chanute, Kansas. The patent references 5 prior patents, including the Durstewitz patent. The others are mostly for digitizing and displaying the measurements. The patent description begins with this:

> *A digital display doppler radar unit has a moving mode and a stationary mode. The incoming Doppler signal, which in the moving mode, represents both speed of the radar platform and speed of an approaching target vehicle, is separated into two signal components by selective filtering. One component represents the sum of the ground speeds for the radar platform and approaching vehicles. A time base is generated by a crystal control means and the time base is utilized for correlating the received doppler signals, indicative of speed, with the time base.*

As in the Durstewitz patent, when the radar is moving, the target speed is combined with the patrol speed and has to be somehow separated. The Aker patent then describes how the information is digitized so that it can be more easily manipulated and displayed. Then it says,

> *The radar signal component representing the ground speed sum for the radar platform and the approaching target vehicle, and the component representing radar platform speed are combined.* ***The radar platform speed is subtracted from the combined component****, resulting in a digital count representing approaching target vehicle speed.*

How the radar gun can determine the "radar platform speed" in order to perform the mathematics is described a few sentences further on in the patent:

> *When the radar platform is moving, at least two doppler return signals are produced simultaneously and these signals create a complex wave form for the radar receiver input.* ***One larger doppler signal component will be generated by the reflected waves from the road and the other stationary objects, with its frequency representing the speed of the radar platform****. A second doppler signal component is generated by the waves reflected from an approaching vehicle, and since the relative speed between the approaching vehicle and the patrol car is the sum of* ***their two ground speeds****, this doppler signal component frequency will represent the sum of two ground speeds.* ***It should be noted that the second doppler signal component's frequency always will be higher than the first if the patrol car and the moving vehicle are traveling in opposite directions. The radar unit of this invention isolates these two doppler signal components by selective filtering.***

Thus the radar gun can distinguish the "radar platform" speed from the target speed due to (#1) the fact that the "Doppler signal" from the ground will generally be stronger, plus (#2) the signal representing the combined patrol and target speeds will *always* be a faster speed than the ground speed when the two vehicles are moving in opposite directions. (Presumably, when the patrol car is *following* the target, making the combined speed *slower* than the target, the intensity of the ground signal still identifies the patrol speed.)

So, if the patrol car is traveling at 50 mph when the officer sees an oncoming car traveling at a much higher speed, the officer then points his “moving mode” radar gun at the oncoming car and the gun shows the target as traveling at 80 mph. To get that number, the gun simply subtracted the slower signal (the ground speed of 50 mph) from the combined signal of 130 mph to get the target speed of 80 mph.

This, of course, would not be possible with waves. That is why the Aker patent refers to “signals” just as the Durstewitz patent referred to “radiations.” Since the speed of light (waves) is fixed, returning waves would totally depend upon the distance to the object that is reflecting the waves. The farther away the target – <u>or part of a target</u> - is, the longer it will take for waves to reflect. Plus, all the return waves will be intermingled with no way to distinguish whether the wave was returned from some part of the ground or some part of the target vehicle. With photons, all photons returning from the ground oscillate the same frequency, and all photons returning from a moving target oscillate a specific *but different* frequency.

VII. The Doppler Effect and Einstein’s Second Postulate.

“The Doppler Effect” describes the change in the observed frequency of sound waves when there is relative motion between the source of the waves and the observer. It was first proposed in 1842 by Austrian mathematician and physicist Christian Johann Doppler. To test Doppler's theory, in 1843 the Dutch meteorologist Christoph Ballot hired 15 trumpeters with precisely-tuned instruments to play on a train as it passed by a group of stationary musicians. The stationary musicians heard a drop in pitch as the train passed by, just as Doppler predicted.

Light consists of photons with oscillating electric and magnetic fields traveling at the speed of light, not waves moving through a medium. And <u>*there is no Doppler Effect due to a radar gun’s motion*</u>. With sound waves, the motion of the emitter changes the distance between waves, and the waves are closer together when the emitter is approaching and farther apart when the emitter is moving away. With photons, virtually *identical* photons are emitted at *c* in all directions regardless of whether the radar gun (the emitter) is stationary or moving.

The stationary-vs-moving problem is routinely compounded by twisting, distorting and misinterpreting Einstein’s two “Postulates.” Here is how Einstein’s two postulates are defined in an English language version of his 1905 paper after providing the examples of magnets and conductors working differently depending upon which is moving and which is stationary:

> Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the “light medium,” suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good. We will raise this conjecture (the purport of which will hereafter be called the “Principle of Relativity”) to the status of a **postulate**, and also introduce another **postulate**, which is only apparently

irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the emitting body. These two **postulates** suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies.**[9]**

The word "postulate" appears nowhere else in the paper. While most people will accept the **first** postulate as being "the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good," many mathematicians will *insist* that the Second Postulate is **not** as Einstein stated it, which is:

"light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the **emitting** body."

Here are just two distorted versions from college physics textbooks:

"Second postulate: The speed of light is a constant and **will be the same for all observers** independent of their motion relative to the light source."**[10]**

The speed of light in free space has the same measured value for **all observers**, regardless of the motion of the source **or the motion of the observer**; that is, the speed of light is a constant.**[11]**

Einstein's Second Postulate says ***nothing*** about what an outside **observer** will see. What an outside observer will see depends upon the movement of that observer. Light travels at *c*, but a moving observer will encounter the light as if the light has more or less energy than what was emitted depending upon the velocity of the observer toward or away from the source of the light.

Einstein didn't just state his Second Postulate one time and leave it to others to be argued about. His subsequent books and papers attempted to explain his theory and his two postulates in greater detail.

Dutch physicist Willem de Sitter observed confirmation of Einstein's Second Postulate in 1913**[12]** and wrote about it in 1916 in "*Einstein's Theory of Gravitation, and its Astronomical Consequences*."**[13]** Albert Einstein used de Sitter's observations in his 1920 book "*Relativity: The Special and General Theory*."**[14]**

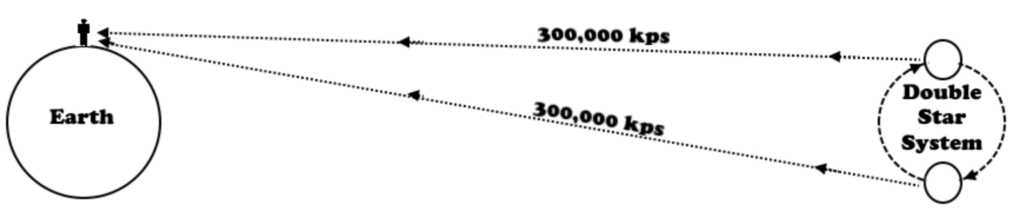

Figure 14

Figure 14 illustrates de Sitter's observation. The two stars in the double star system orbit each other, which means that when one star is moving toward the earth, the other is moving away from the earth. According to Isaac Newton and Swiss theoretical physicist Walther Ritz, the light from the star moving toward the earth should travel at *c+v*, where *v* is the speed of the star toward earth, and the light from the star moving away from the earth should travel at *c-v*. That became known as “Emission Theory.” De Sitter’s observations showed that “Emission Theory” was *not true*. The light travels at 299,792 kilometers per second (kps) (usually rounded to 300,000 kps) from *both* stars. If “Emission Theory” were true, that would also mean that, while the slow-moving light from the receding star is traveling to the earth, the faster-moving light from the oncoming star would pass by the slower-moving light, and an observer on earth would see the same star in different locations. That doesn’t happen.

Einstein agreed. He decided there must be a *maximum speed limit* in our universe that prevents light from traveling faster than 299,792 kps. And all light *must* be emitted at 299,792 kps *in all directions*. That means that, no matter how fast a light source is traveling, *or in what direction*, the light that the source emits will travel at 299,792 kilometers per second, **as a second is measured at the emission location**.

This also means that an observer who is **stationary** relative to the emitter will see that light arrive at 299,792 kps regardless of how fast or in what direction the emitter and observer are moving. But, if the observer is **moving** toward or away from the light source/emitter, the light photons will arrive with different energy, depending upon the velocity of the observer.

VIII. The Problem.

When discussing “stationary” versus “moving” radar guns, you need to define what the words “stationary” and “moving” actually mean. After all, the radar gun you hold in your hand as you sit “stationary” in a parked patrol car beside a highway is actually moving at about 750 miles per hour as the earth spins on its axis, it is moving around the Sun at 67,000 miles per hour, it is moving with the Sun around the center of the Milky Way at 486,000 miles per hour, and the Milky Way Galaxy is moving toward the Hydra constellation at 1,342,161 miles per hour.

The gun is only “stationary” relative to the ground, i.e., the surface of the earth on which the patrol car is parked. All measured “movement,” therefore, is relative to the surface of the earth. And that is the movement the gun will measure – **even when the gun is moving**.

As stated in Section I, radar guns emit a stream of trillions of photons for as long as the trigger is pulled. If the radar gun is in a vehicle such as a police patrol car that is moving across the surface of the Earth, the movement of the patrol car across Earth’s surface has no significant effect on the photons the gun emits. According to Einstein’s Velocity Time Dilation, time runs a bit slower for the moving gun than for the earth. That is because the earth is a quasi-inertial system. An “inertial system” is a frame of reference in which a body remains at rest or moves with constant velocity in a straight line unless acted upon by forces. The earth is not totally inertial, since it is not moving in a straight line, but it moves without force being applied, and an object on its surface moves in almost a straight line if the duration of the movement is not very long. So, it is "quasi-inertial," i.e., close enough to be viewed as inertial in most situations.

That means Time will run a bit slower for the moving radar gun than for a stationary object on the surface of the earth, like a parked car or a highway sign. Because a second is longer for the moving radar gun, photons the moving gun emits will travel very slightly slower **per second** than photons emitted from a stationary radar gun. And that is where Einstein's Second Postulate becomes important. Because photons emitted by the moving radar gun travel at velocity *c* which is independent of the state of motion of the radar gun, the photons will travel as if they were emitted by a stationary radar gun. The photons will hit a parked car or a highway sign just as if they had been emitted by a stationary radar gun. Atoms in the parked car or the highway sign will emit new photons back to the radar gun that are **identical** to what the gun emitted. And, of course, the motion of the earth does not affect the speed of the photons.

The photons that return to the moving radar gun, however, will hit the gun's receiver with more energy than was emitted. The gun's speed does *not* affect the photons that are emitted, but it *does* affect any photons that are received. If the gun is moving at 50 mph, a "stationary only" radar gun will display 50 mph as the measured speed, while a "moving mode" radar gun will show 50 mph as the "patrol speed." If there is a moving target somewhere within the cone of photons, the gun will still measure 50 mph as the "patrol speed" because it is the strongest signal (more photons came back from the ground than from the moving target).

According to one book on radar principles, one manufacturer developed a radome to fit over the front of the gun to purposely reflect some of the emitted RF (Radio Frequency) photons back into the receiver in order to provide the gun with a better LO (Local Oscillator) signal:

> Kustom [Signals, Inc.] developed a plastic radome that fit over the end of the horn to purposely reflect a small amount of RF power back into port 2 and create an LO reference signal at the required mixing level.**[15]**

What this does is enable the radar gun to generate additional photons representing a stationary radar gun which can be compared to the photons returning from the target.

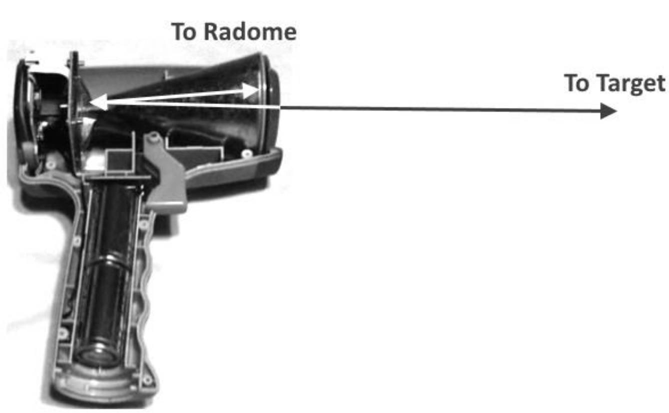

Figure 13

Figure 13 shows a radar gun emitting photons, most of which travel to the target, but some of which travel only to the semi-transparent radome covering the front of the gun. If the radar gun is moving forward, the photons hit tiny particles in the radome at *c*. The atoms in those particles then emit **new** photons back into the interior of the gun. Because the radome is stationary relative to the rest of the gun, those new photons hit the receiver at *c*. Thus, whether the gun is moving or stationary, the photons sent to and received from the radome are measured by the gun to have the same oscillation rate as the photons the gun emitted toward the target.

Meanwhile, photons that pass through the semi-transparent radome will be received by a target as if they have more energy or less energy per photon depending upon the direction the target is moving at velocity *v*. If we assume the target is coming toward the radar gun, atoms in the target emit new photons back to the radar gun with a higher oscillation rate (more energy). Those photons mix with the returning photons from the radome, and when compared in a "mixer," they show the "beat frequency," which is equal to the speed of the target when the gun is stationary and equal to the *combined* speed of the gun *and* the target when the gun is moving. All that the semi-transparent radome accomplished was to provide a lot more photons for comparison to the photons returning from the target.

IX. How radar guns work when moving.

1. Moving radar gun, stationary target.

Because the speed of the emitter does not change the speed of the light that is emitted, a moving radar gun traveling at 50 mph emits photons with electric and magnetic fields that oscillate at the same rate as if the gun was stationary. If those photons hit a parked car, the photons that return from the parked car to the gun will oscillate at the same frequency used by the gun. However, when photons return from a target, those photons will hit a moving radar gun. The moving radar gun will add kinetic energy to the arriving photons, accepting them as if they have a higher oscillation frequency than what was emitted by the parked car.

When the gun processes those photons, it will compute a speed of 50 mph. If it is a "stationary only" radar gun being used improperly from a moving vehicle, it will just show a speed of 50 mph. It is the speed of the gun, **not** the speed of the target. I've used my TS-3 radar gun this way many times. **The radar gun is measuring its own speed** by bouncing photons off of a stationary target. If the gun is a "moving mode" type radar gun, it will display 50 mph as the "patrol speed" because photons returning from the ground and other stationary objects around the parked car also sent back photons that oscillated at the same rate as the photons that were received.

2. Moving radar gun, oncoming target.

If the radar gun is moving at 40 mph toward a target that is approaching at a ground speed of 60 mph, the emitted photons will hit the **oncoming moving** target with added energy equivalent to 60 mph, due to the Compton Effect. The returned photons will then hit the moving radar gun with additional Compton Effect energy equivalent to 40 mph. The gun then compares the photons it emitted to photons it received back and computes a speed that is the speed of the gun plus the speed of the target. If it is a "stationary only" gun, it will display the combined speed of 100 mph. (I've verified this with my TS-3 radar gun many times.) If it is a "moving mode" gun, it will display a "target speed" of 60 mph and a "patrol speed" of 40 mph.

3. Moving radar gun, receding target.

If the radar gun is moving at 40 mph toward a target that is moving away at a ground speed of 60 mph, because the speed of the emitter has no effect on the speed of the emitted photons, the emitted photons will hit the **receding moving** target as if the target was moving at 60 mph away from the gun. Due to the Compton Effect, the returning photons will have a lower oscillation frequency than the emitted photons. And those photons will then hit the radar gun's receiver at with added Compton Effect energy equivalent to 40 mph. A "stationary only" radar gun has no ability to display negative numbers, so it will display a target speed of 20 mph. If it is a "moving mode" radar gun, it should show 40 mph as the patrol speed and -60 mph as the target speed.

X. Conclusion

Radar guns demonstrate that light consists of photons with oscillating electric and magnetic energy fields, not waves. In accordance with Einstein's Second Postulate to his Theory of Special Relativity, photons are emitted and travel at c, regardless of the speed of the radar gun. When those photons hit a moving target, the target emits new photons back to the radar gun that oscillate at higher or lower frequency, indicating that the Compton Effect changed the energy of the returned photons and the cosine effect can further modify that energy. The gun then compares the emitted and returned frequencies and computes the speed of the target. Time dilation plays no role in the operation of radar guns. If it did, there would be no cosine effect.

XI. References

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